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ENGINEER'S FIELD BOOK.

NEW YORK:
1886.

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ENGINEER'S

FIELD BOOK.

By C. S. CROSS, Civil Engineer.

SECOND EDITION

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RAILROAD CURVES.

The following tables show the distance from the point of intersection of the tangent lines to the beginning of a one degree curve, the angle of deflection (=angle at centre) being known.

In the columns, under the head of degrees and opposite the minutes, are given the distances in feet from the intersection of tangents to the beginning of one degree curve.

To ascertain the distance for any given degree of curve, divide the distance given in the tables for a One degree curve, by the degrees of the required curve, and you have the distance from the point of intersection to the beginning or end of curve.

EXAMPLE:

Required the distance from the point of intersection of tangents to the beginning of a Two degrees curve, the angle of deflection being 25°.

In the tables under 25°, and opposite 0′, find 1270.28 which divided by the degrees of the curve (2°) give 635.14 feet, the required distance.

In staking the centre line for a railroad or a canal, stakes should be driven down to near the surface of the ground, at the intersection of the tangents, and at the different stations; and nails set in indicating the centre point. These stakes serve also for leveling purposes and are useful in detecting errors while the work is being relevelled and staked out.

The beginning and end of curves should have reference stakes set at right angle to the centre line, similarly driven and marked, and at such convenient distance from the centre as will insure them from being displaced in making excavations and embankments; and at all the above named points another stake for numbering, &c., should be firmly driven adjacent to them.

The radius of a One degree curve is 5730 feet. The circle being divided into 360 parts of one degree (equal angle of deflection) give 360 chords of one foot in length at the circumference, and also a radius of 57.3 ft. thus:

$$\frac{360}{3.1416} = \frac{114.6}{2} = 57.3$$

The chord of One foot in length for 1 degree = 57.3 ft. Radius.

" 10 feet " " " = 573.0 "

" 100 " " " " = 5730.0 "

Or the radius may be calculated by natural sines, thus:

sin. 1°: 100 ft. chord : : sin. 89° 30′ : 5730 ft. radius.

To determine the degree of curvature, having the radius given, divide the radius of a One degree curve, 5730, by the radius of the given curve.

EXAMPLE:

Required the degree of a curve having a radius of 1000 feet:

$$\frac{5730}{1000} = 5.73° = 5° 43′ 48″$$

To determine the length of the curve having the angle of deflection given; divide the angle of deflection (=angle at centre) by the degrees of the curve, and you have the required length of the curve. If there are degrees and minutes in the angle of deflection, the minutes should be converted into decimals.

EXAMPLE:

The angle of deflection being 20° 49′, $\frac{49}{60} = 0.816$. Then 20.816 is the distance for a One degree curve; if for a 2 degrees curve, divide this result by 2; for a 3 degrees curve, divide by three, and so on.

The angle of deflection being given, the following results are readily determined:

Angle of deflection	Degree of curve	Deflection per 100 feet.	Radius of curve	Dist. from intersec. to beginning of curve.	Length of curve.
20° 49′	1°	0° 30′	5730.	1052.49	2081.6
20° 49′	2°	1° 00′	2865.	526.24	1040.8
20° 49′	3°	1° 30′	1910.	350.83	693.8
20° 49′	4°	2° 00′	1432.5	263.12	520.4
20° 49′	5°	2° 30′	1146.	210.50	416.3

To ascertain the radius of a curve, having the angle of deflection, and the distance from intersection to beginning of curve given. Find the distance for the angle of deflection in the tables, which divided by 5730. gives the natural tangent of half the angle.

Then divide the distance from intersection to beginning of curve by the natural tangent of half the angle, and you have the radius.

EXAMPLE:

Required the Radius of a curve, the angle of deflection being 20°, and the distance from intersection of tangents to beginning of curve 225 feet.

Under 20° and opposite 0′ in the tables, find 1010.37, which divided by 5730 feet gives the natural tangent 0.17633. Then 225 ft. divided by 0.17633 gives the radius 1276 feet.

FIELD NOTES FOR A ONE DEGREE CURVE.

Bearing of 1st tangent . . . . . N. 20° W.
" 2d. " . . . . . N. 40° W.
Angle of deflection by needle . . . . . 20°
" " " graduated card . . . 20°

The angles measured with the card are the most reliable; but the angles by the needle although it often indicates a slight differ-

ence, serves as a check to greater errors which may arise in reading the degrees on the graduated limb of the instrument.

* Station No. 506.2000 Intersection of tangents.

— 10.1037 from intersection to beginning of curve.

* Station No. 496.0963 point at which curve commences.

\+ 20.0000 length of curve.

* Station No. 516.0963 point at which curve terminates.

DEFLECTION FROM TANGENTS.

Stations.	Length of chords in feet.	Deflection from tangent.	REMARKS.
496.096	" "	" "	* Beginning of curve.
497.	90.37	0° 27	1° to left. (Tang. due N.)
498.	100.00	0° 57	
499.	100.00	1° 27	
500.	100.00	1° 57	
501.	100.00	2° 27	
502.	100.00	2° 57	* Change point.
503.	100.00	3° 27	
504.	100.00	3° 57	
505.	100.00	4° 27	
506.	100.00	4° 57	
507.	100.00	5° 27	
508.	100.00	5° 57	
509.	100.00	6° 27	* Change point.
510.	100.00	6° 57	
511.	100.00	7° 27	
512.	100.00	7° 57	
513.	100.00	8° 27	
514.	100.00	8° 57	
515.	100.00	9° 27	
516.	100.00	9° 57	
516.0963	9.63	10° 00	* End of curve. (Tangent N. 20° W.)

FIELD NOTES FOR A TWO DEGREES CURVE.

Bearing of 1st tangent..... N 10° W.
" 2d " ..... N 30° W.
Angle of deflection by needle..... .... 20°
" " by graduated card..... 20°
Station... 506.200 intersection of tangents.
— 5.052 from do. to beginning of curve.

Station.... 501.148 point at which the curve commences.
+ 10.000 length of the curve.

Station.... 511.148 point at which the curve terminates.

DEFLECTION FROM TANGENTS.

Stations.	Length of chords in feet.	Deflection from tangent.	REMARKS.
501.148	,, ,,	0° 00′	* Beginning of curve 2° to left.
502.	85.20	0° 51	(Tangent N 10° W.)
503.	100.00	1° 51	
504.	100.00	2° 51	
505.	100.00	3° 51	
506.	100.00	4° 51	
507.	100.00	5° 51	* Change point.
508.	100.00	6° 51	
509.	100.00	7° 51	
510.	100.00	8° 51	
511.	100.00	9° 51	
511.148	14.80	10° 00	* End of curve. (Tangent N 30° W.)

In curves of great length, the instrument should be moved forward in about every five or six hundred feet to insure accuracy, and often to avoid obstruction in line. The mode of proceeding in such cases may be illustrated with the deflections of the 2° curve.

The instrument in the first place is set at station 501.148 and the deflection from tangent to station 507 is 5° 51′. Now change the position of the instrument to station 507, and bring the cross hairs to bear on the staff at station 501.148; after clamping the instrument turn with the vernier as a test

for station 502,	0°51′
for " 503,	1°51′
for " 504,	2°51′
for " 505,	3°51′
and for the tangential station 507,	5°51′ * Ch. pt.

If the stakes are found to be correct, continue the setting of the remaining stakes to end of curve, and deflect the degrees from the beginning of curve given in the field notes opposite the respective stations.

When an odd number of minutes are to be turned off at the commencement and for each successive station, the inconvenience may be obviated by setting the vernier the number of minutes for the required chord in an opposite direction from that in which you would turn for the stations in the curve; or so that the instrument when set in line with the tangent and clamped, the nonius instead of reading 0, will indicate the number of degrees or minutes which would be deflected to strike in line with the first stake to be set in the curve. Then the remainder of the stations will be free from the odd minutes which would otherwise be turned off for each successive station.

When the instrument is moved forward to another station, the same mode may be adopted with reference to setting the nonius preparatory to bringing the cross hairs to bear on the staff at the beginning of curve.

By determining the tangents at the various points in the curve over which the instrument may be set, the staking of the curve may be prosecuted with less liability to error.

At the end of curve the instrument should be set over the stake to ascertain if the tangent produced from deflection corresponds with the course and direction of the tangential line.

Field Notes and method of staking a 3 ° Curve.

Bearing of 1st tangent, N. 20° W.
" 2d " N. 40° W.
Angle of deflection by needle 20°.
" " by graduated card 20°.

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* Station . . 506.180 intersection of tangents.
— 3.368 from do. do. to beginning of curve.

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* Station . . 502.812 point at which the curve commences.
+ 6.666 length of curve.

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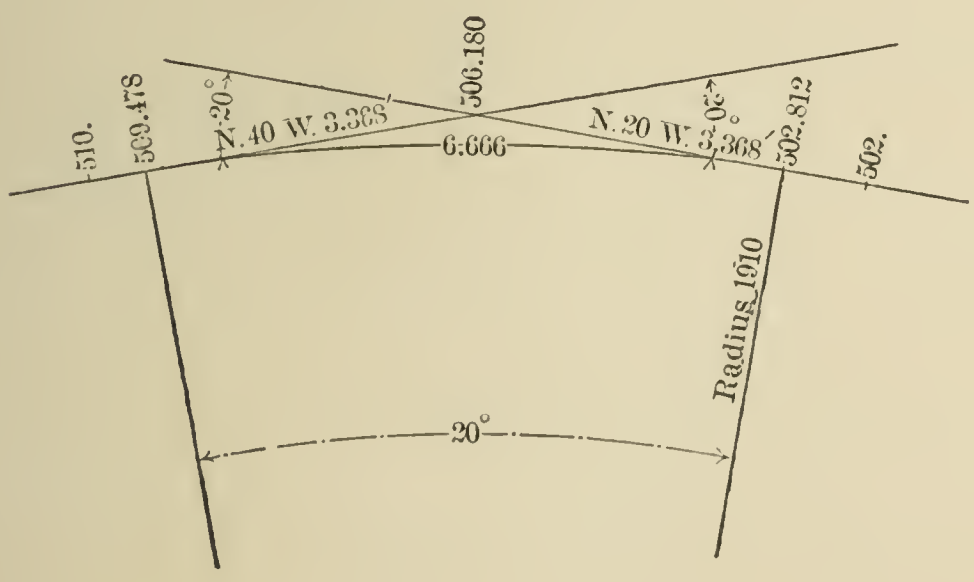
* Station . . 509.478 point at which the curve terminates.



The notes are put down as represented in this diagram, and numbered from right to left when curving to the left, and from left to right when curving to the right.

FIELD NOTES.

No. of Station	Length of chords.	Course of tangents and chords.	Deflect'n from tangent.	REMARKS.
502.812	" "	N 20° W	0° 0′	* B. C. 3° to left.
503.	18.8	20° 17′	0° 17′	
504.	100	22. 04	1. 47	
505.	100	25. 04	3. 17	* Change point.
506.	100	28. 04	4. 47	
507.	100	31. 04	6. 17	
508.	100	34. 04	7. 47	
509.	100	37. 04	9. 17	
509.478	47.8	29. 04	10. 00	* E. C.
510.	52.2	N 40° 00 W		

The number at which the curve ends should be given to the chainman before proceeding to measurement, so that the proper signal may be made by him on arriving at the station next preceding the termination of the curve.

Then set the instrument over the point of curve at station 502.812 and deflect from the tangent line for station 503, 0° 17′
" " 504, 1° 47′
" " 505, 3° 17′

and so on to the end of curve as per column of deflection, unless the instrument is moved forward. If it is necessary to move the instrument, then set it over another stake in the curve, bring the cross hairs to bear on the staff at the beginning of curve and clamp the instrument; then turn off for the tangent at the station selected, the same number of degrees originally turned from tangent at beginning of curve in setting the stake, and 1° 30′ additional for each successive station of 100 feet as you advance; the angles should correspond with those given in the column of deflections set opposite the respective stations.

It frequently occurs that the instrument has to be changed to points intermediate between two stations.

If in a five degrees curve, for instance, it is necessary to change the instrument from station No. 0, there being an obstruction in

the line of sight between station 0 and station No. 3, and nothing to prevent the instrument being set over a point in the curve 30 feet distant from station 2; the deflections would be made as follows:

Station	0	Deflection =	0° 00	B. C. 5° R.
"	1	"	2° 30.	
"	2	"	5° 00.	
"	2.30	"	5° 45.	* Change point.

Then move the instrument forward, and set it over station 2.30, and bring the cross hairs to bear on the staff at the beginning of the curve, station 0; then turn off 5° 45′ for tangent at station 2.30 and 1° 45′ for 70 feet the remainder of station No. 3, making in all for station No 3—deflections 7° 30′

"	4	"	10° 00′	
"	5	"	15° 00′	E. C.

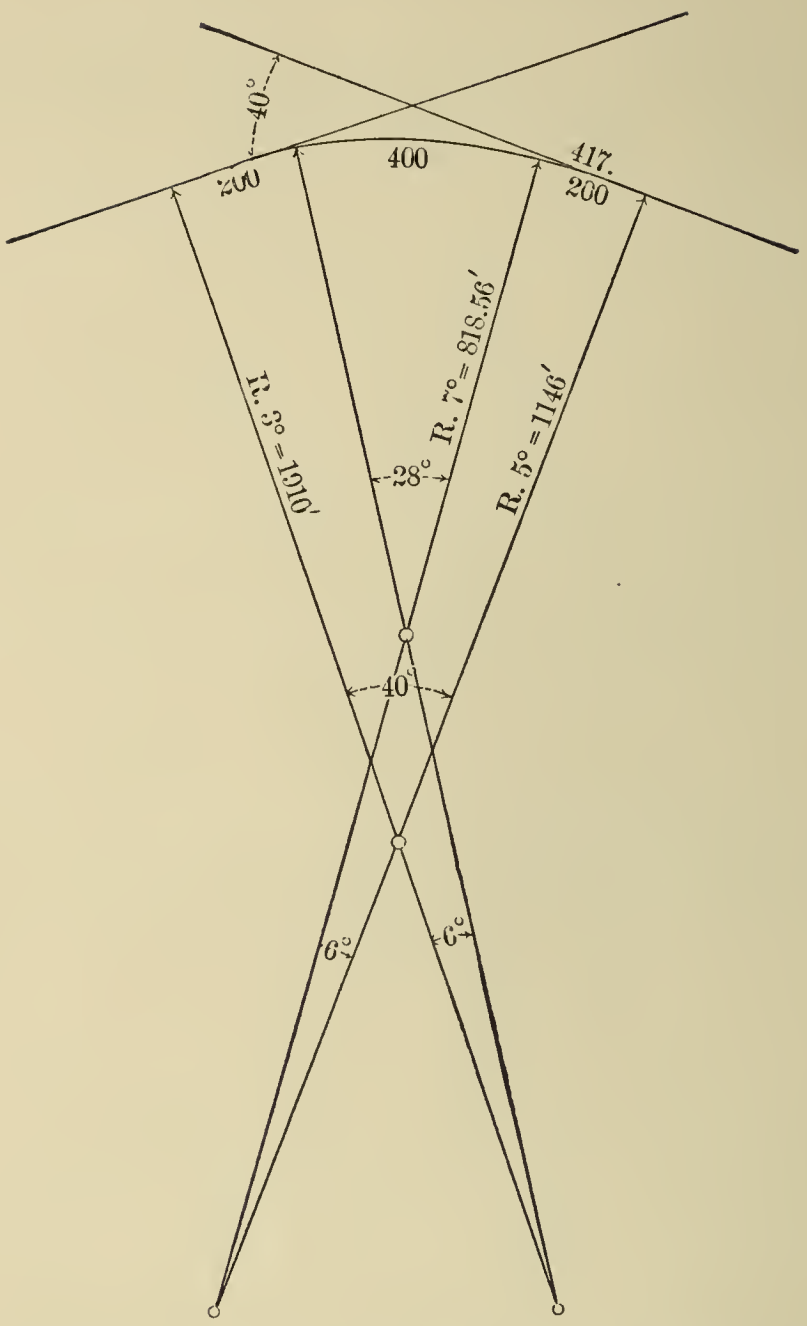
The angles for parts of a station on curves may be readily calculated and the angles turned off in such manner as will keep the stations of uniform length throughout the line.

REVERSE CURVES.

These may be put in according to the formation of the ground with equal radii, or not, as the case may require. In the latter case the degree of curve may be assumed and the curve continued as far as deemed necessary; and the tangent is then produced to the intersection and measured—and the angle of deflection determined. These give the data from which the radius and degree of curve are determined.—*See Pages* 6 *and* 7.

In the former case select a point in one of the tangents and turn from tangent such angle as the case may require, and measure on this line the distance between the tangents. Then set in a point one half of this distance for the point of reversion, from which both curves may be staked out.—*See Pages* 6 *and* 7.

If you wish to compound a curve so that the trains will pass less abruptly from tangent into and through the curve, it may be done in the following manner:



We will assume the angle of deflection to be 40°; in the tables under 40° and opposite 0′ find 2085.55, the distance from intersection of tangents to beginning of a one degree curve.

If you wish to lay out a compound equivalent to a curve of 5° for the whole angle, divide the distance found (2085.55) by 5, degree of the curve; and you have the point of beginning 417 ft. from intersection of tangents. You will then decide on what length to substitute the less degree of curve.

If a 3° curve is decided on, and the distance 200 feet at each end of the 5° curve, then deduct 3° for each station of 100 feet, making

12° from the total angle of deflection, (40°) and you have 28° to be divided equally between the stations of the intermediate curve, or $\frac{28}{4} = 7°$, the required degree of curve.

FIELD NOTES.

No. of Station.	Course of chords.	Deflection.	REMARKS.
No 0.	" "	0° 00′	Beginning of curve,
1	N 1° 30′ W	1° 30′	
2	4 30	3 00	End of curve, 3°, B. C. 7°
3	9 30	3 30	From tangent.
4	16 30	7 00	
5	28 30	10 30	
6	30 30	14 00	E. C. 7°, B. C. 3°.
7	35 30	1 30	From tangent.
8	38 30	3 00	E. C. 3°. Tangent, N 40° W.

NATURAL TANGENTS.

From the tables may also be determined the natural tangent for any given number of degrees and minutes from one degree to 45°, by taking the distance given in the tables for twice the angle of which the tangent is sought, and dividing the same by 5730.

EXAMPLES :

1st. Required the natural tangent of 30°. Under 60° (twice the angle) find in the tables 3308.21 and divide the same by 5730, and you have the natural tangent for 30° = 0.57735.

2d. Required the natural tangent for an angle of 7° 28′; in the

column of distances under 14° and opposite 56′ (twice the angle) find 750.97, which divided by 5730 give the natural tangent for 7° 28′ equal to 0.13106.

MEASUREMENT WITH GUNTER'S CHAIN.

When a 66 feet chain is used for the length of stations, the radius of a one degree curve, 5730 feet, may represent 57.30 chains of 66 feet, and the distances in the tables applied the same as for chains of 100 feet in length; but the radius as well as the length of stations will be proportionally less than for stations of 100 feet in length by $\frac{1}{34}$ part.

If a 66 feet chain is used, the distance after being found in the tables, may be divided by 66, and the stations in the curve reduced to 75.76 links which are equal to 50 feet, one half the length of the stations generally adopted in staking the center line of railroads; and the curve staked out accordingly, turning off one half the number of degrees required for the stations of 100 feet in length.

The degree of curvature is understood to express the number of degrees per 100 feet, and hence the convenience of making the stations of such length as will give a definite idea of the degree of curve and length of radius.

The following abbreviations are used by some Engineers.

P. C. For Point of Curve, or Beginning of Curve.

P. T. " " " Tangent, or End of Curve.

P. C. C. " " " Compound Curve—or end of one curve and beginning of another, curving in the same direction.

P. R. C. " " " Reverse Curve, or point where the direction of the curve is changed from right to left, or *vice versa.*

P. I. " " " Intersection of Tangents.

CONTENTS.

RAILROAD CURVE TABLE.

The following Table shows the distance from the point of intersection of the Tangent lines to the beginning of one degree curves, for each 30 feet, the angle of deflection (=angle at centre) being known.

I. = The given angle of deflection.

II. = The sought for distance.

III. = Difference for intermediate angles.

RAILROAD CURVE TABLE.

I	II	III	I	II	III	I	II	III
0° 0′	25.00	25.0	30° 30′	1562.17	26.8	60° 30′	3341.62	33.4
1	50.02	25.0	31	1589.04	26.9	61	3375.20	33.6
1 30	75.01	25.0	31 30	1616.03	27.0	61 30	3408.95	33.8
2	99.99	25.0	32	1643.08	27.0	62	3442.93	34.0
2 30	125.03	25.0	32 30	1670.12	27.0	62 30	3477.02	34.1
3	150.07	25.0	33	1697.28	27.2	63	3511.34	34 3
3 30	175.05	25.0	33 30	1724.56	27.3	63 30	3545.78	34.4
4	200.09	25.0	34	1751.83	27.3	64	3580.45	34.7
4 30	225.13	25.0	34 30	1779.22	27.4	64 30	3615.34	34.9
5	250.17	25.0	35	1806.67	27.4	65	3650.41	35.1
5 30	275.21	25.0	35 30	1834.17	27.5	65 30	3685.65	35.2
6	300.30	25.0	36	1861.79	27.6	66	3721.06	35.4
6 30	325.35	25.0	36 30	1889.47	27.7	66 30	3756.70	35 6
7	350.44	25.1	37	1917.26	27.8	67	3792.57	35 9
7 30	375.54	25.1	37 30	1945.05	27.8	67 30	3828.61	36.0
8	400.70	25.1	38	1973.01	27.9	68	3864.88	36.3
8 30	425.79	25.1	38 30	2001.03	28.0	68 30	3901.38	36.5
9	450.95	25.1	39	2029.11	28.1	69	3938.11	36.7
9 30	476.10	25.1	39 30	2057.30	28.2	69 30	3975.01	36.9
10	501.32	25.2	40	2085.55	28.3	70	4012.15	37.1
10 30	526.53	25.2	40 30	2113.91	28.4	70 30	4049.56	37.4
11	551.74	25.2	41	2142.33	28.4	71	4087.15	37.6
11 30	576.95	25.2	41 30	2170.92	28.6	71 30	4124.97	37.8
12	602.22	25.3	42	2199.52	28.6	72	4163.07	38.1
12 30	627.55	25.3	42 30	2228.28	28.8	72 30	4201.41	38.3
13	652.87	25.3	43	2257.10	28.8	73	4239.97	38.6
13 30	678.20	25.3	43 30	2286.04	28.9	73 30	4278 76	38.8
14	703.53	25.3	44	2315.09	29.0	74	4317.84	38.9
14 30	728.97	25.4	44 30	2344.20	29.1	74 30	4357.15	39 3
15	754.35	25.4	45	2373.42	29.2	75	4396.74	39.6
15 30	779.79	25.4	45 30	2402.76	29.3	75 30	4436.62	39.9
16	805.29	25.5	46	2432.21	29.4	76	4476.73	40.1
16 30	830.79	25.5	46 30	2461.78	29.6	76 30	4517.13	40 4
17	856.35	25.5	47	2491.46	29.7	77	4557.81	40.7
17 30	881.90	25.5	47 30	2521.26	29.8	77 30	4598.78	41.0
18	907.52	25.6	48	2551.11	29.8	78	4640.04	41.3
18 30	933.18	25.6	48 30	2581.13	30.0	78 30	4681.58	41.5
19	958.86	25.7	49	2611.27	30.1	79	4723.41	41.8
19 30	984.58	25.7	49 30	2641.53	30.3	79 30	4765.58	42.2
20	1010.37	25.8	50	2671.90	30.4	80	4808.04	42.5
20 30	1036.15	25.8	50 30	2702.44	30.5	80 30	4850.79	42.7
21	1062.00	25.8	51	2733.04	30.6	81	4893.88	43.1
21 30	1089.90	25.9	51 30	2763.81	30.8	81 30	4937.25	43.3
22	1113.80	25.9	52	2794.69	30.9	82	4980.97	43.7
22 30	1139.75	25.9	52 30	2825.69	31.0	82 30	5025.04	44.1
23	1165.76	26.0	53	2856.86	31.2	83	5069.44	44.4
23 30	1191.84	26.1	53 30	2888.15	31.3	83 30	5114.20	44.8
24	1217.96	26.1	54	2919.55	31.4	84	5159.29	45.1
24 30	1244.10	26.1	54 30	2951.12	31.6	84 30	5204.73	45.4
25	1270.28	26.2	55	2982.81	31.7	85	5250.57	45.8
25 30	1296.58	26.3	55 30	3014.67	31.9	85 30	5296.75	46.2
26	1322.88	26.3	56	3046.64	32.0	86	5343.28	46.5
26 30	1349.24	26.4	56 30	3078.79	32.2	86 30	5390.21	46.9
27	1375.65	26.4	57	3111.10	32.3	87	5437.54	47.3
27 30	1402.10	26.4	57 30	3143.53	32.4	87 30	5485.27	47.7
28	1428.65	26.5	58	3176.14	32.6	88	5533.35	48.1
28 30	1455.25	26.6	58 30	3208.91	32.8	88 30	5581.88	48.5
29	1481.89	26 6	59	3241.86	32.9	89	5630.81	48.9
29 30	1508.59	26.7	59 30	3274.92	33.1	89 30	5680.20	49.4
30	1535.30	26.7	60	3308.21	33.3	90	5730.00	49.8

RAILROAD CURVES.

THE FOLLOWING TABLE SHOWS THE METHOD OF

KEEPING THE FIELD NOTES

OF A SURVEY, FROM WHICH THE CENTER LINE IS LAID ON THE MAP

From station.	To station.	Length of tangents in feet.	Length of curves in feet	Angle at intersection of tangents or angle at centre.	Course of tangent, and degree and direction of curves.	Radius of curves in feet.	No. of ft. from intersection of tangents to begng. of curve.
.....	.....	.....	.....	Tangent	S 19° 21′ E		
0.	2.		200.	7° 24′	3° 42′ L	1548.65	100.14
2.	26.		2400.	24° 00′	1° 00′ R	5730.	1217.96
26.	43.556	1755.60		Tangent	S 2° 45′ E		
43.556	61.681		1812.5	36° 15′	2° 00′ R	2865.	937.82
61.681	93.650	3196.90		Tangent	S 33° 30′ W		
93.650	102.517		886.7	13° 18′	1° 30′ L	3820.	445.37
102 517	143.90	4138.30		Tangent	S 20° 12′ W		
143.90	155.766		1186.66	23° 44′	2° 00′ L	2865.	602.02
155.766	170.43	1466.40		Tangent	S 3° 32′ E		
170.43	181.296		1086.66	21° 44′	2° 00′ R	2865.	550.00
181.296	184.506	321.00		Tangent	S 18° 12′ W		
184.506	193.195		868.89	13° 02′	1° 30′ R	3820.	436.37
193.195	213.064	1986.9		Tangent	S 31° 14′ W		
213.064	220.908		784.44	11° 46′	1° 30′ L	3820.	393.61
220.908	230.546	963.8		Tangent	S 19° 28′ W		
230.546	242.496		1195.00	23° 54′	2° 00′ R	2865.	606.37
242.496	252.356	986 00		Tangent	S 43° 22′ W		
252.356	263.756		1140.00	17° 06′	1° 30′ L	3820.	574.30
263.756	266.02	226.40		Tangent	S 26° 16′ W		
266.02	268.02		200.00	3°	1° 30′ L	3820.	100.05
268.02	277.21		918.89	27° 34′	3° L	1910.	468.55
277.21	279.21		200.00	3° 00′	1° 30′ L	3820.	100.05
279.21	289.011	980.1		Tangent	S 7° 18′ E		
289.011	291.011		200.00	3° 00′	1° 30′ R	3820.	100.05
291.011	301.422		1041.10	31° 14′	3° 00′ R	1910.	533.88
301.422	303.00		157.80	2° 22′	1° 30′ R	3820.	78.90
303.00	321.00	1800.		Tangent	S 29° 18′ W		
321.00	334.00		1300.	26°	2° L	2865.	661.41
334.	338.71	471.00		Tangent	S 3° 18′ W		
338.71	347.15		844.16	16° 53′	2° 00′ R	2865.	425.19
347.15	364.00	1685.00		Tangent	S 20° 11′ W		
364.	376.633		1263.33	37° 54′	3° R	1910.	655.80
376.633	389.53	389.70		Tangent	S 58° 05′ W		
380.53	392.38		1185.	23° 42′	2° R	2865.	601.14
392.38	402.92	1054.00		Tangent	S 81° 47′ W		
402.92	404.92		200.	3° 00′	1° 30′ L	3820.	100.05
404.92	418.198		1327.77	39° 50′	3° 00′ L	1910.	632.04
418.198	420.198	200.		Tangent	S 38° 57′ W		
420.198	441.002		2080.41	83° 13′	4° L	1432.	1272.21
441.002	442.582		158.	4° 00′	2° 32′ L	2261.87	79.99
442.582	449.	641.8		Tangent	S 48° 16′ E		
		22.262.90	22.637.31				

APPLICATION OF THE PRISMOIDAL FORMULA

IN DETERMINING THE QUANTITIES OF RAILROADS AND CANAL EXCAVATIONS AND EMBANKMENTS.

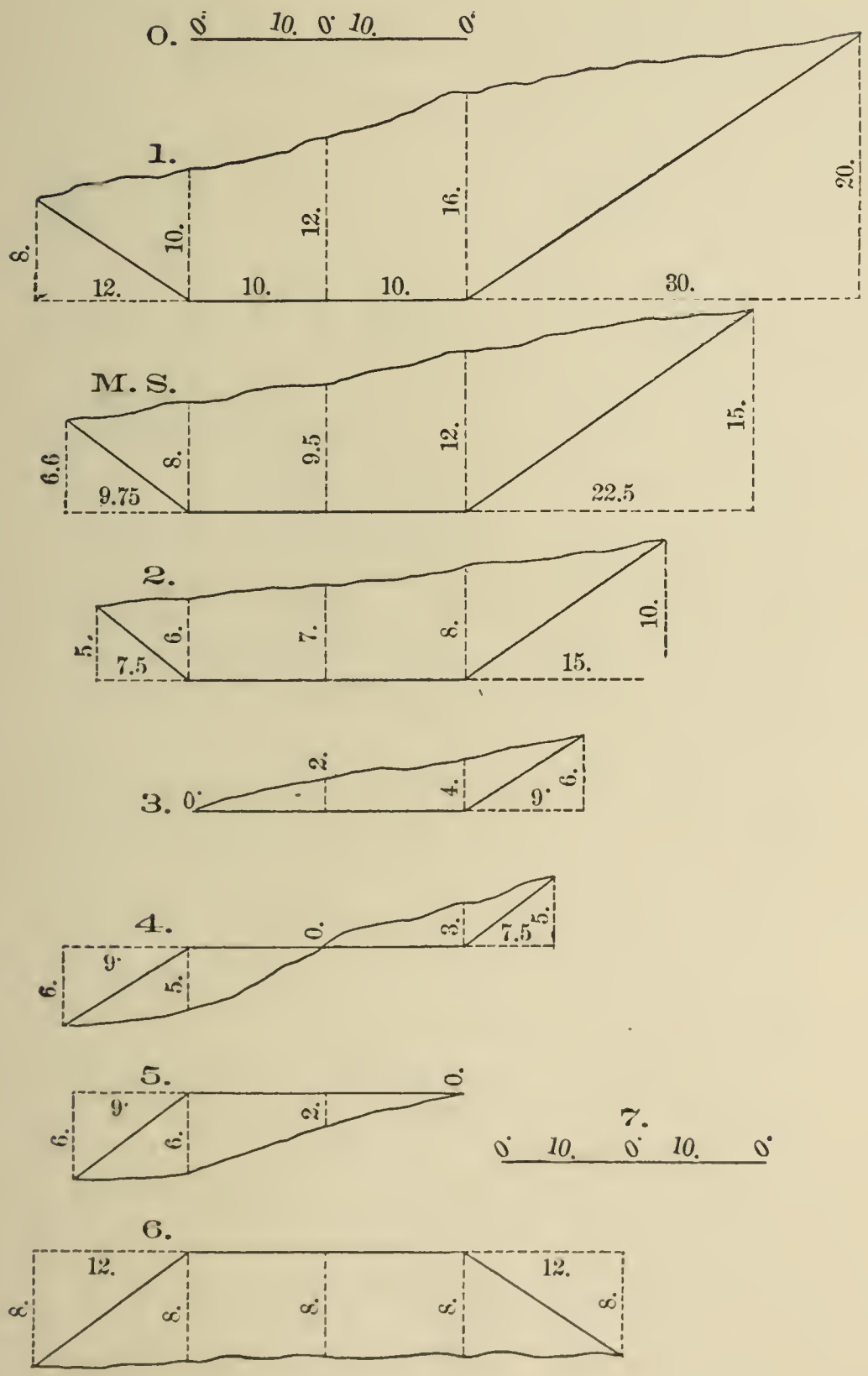
In order to obtain the mean area from transverse sections, construct from the average cuttings and average horizontal distances of the slopes of the end section, a middle section; and add to four times the area of this section the area of the end sections, and take one-sixth of the product for the mean area.

The following diagrams show most of the figures which occur in taking cross sections of railroads, and serve to illustrate the application of the formula. In practice, however, intermediate sections would be taken between station 0 and station 1, and at such other points as any sudden or material change in the surface would seem to require.

The cuttings and horizontal distances from the centre to the termination of the slopes, are set down in tabular form. The notes of the middle section may at convenience be interlined in the space between the notes of the end sections. From this form the factors for the areas are made without resorting to diagrams.—*Page* 34.

*It will be seen by inspecting the diagrams that the embankment between stations 3 and 4 assumes the shape of a pyramid, and hence one-third of the area of the embankment set opposite station 4, should be multiplied by the distance between stations 3 and 4 to obtain the quantity. Between stations 4 and 5 the excavation assumes the same form, and should also be calculated as a pyramid; or construct the middle section as before described, and calculate the distance from the centre to the point where the surface and the grade intersect; and make out the factors accordingly.

Having obtained the mean areas, proceed as hereinafter described to ascertain the cubic yards.


0.
0. 10. 0. 10. 0.
1.
8.
12.
10.
12.
10.
16.
10.
20.
30.
M. S.
6.6
9.75
8.
9.5
12.
15.
22.5
2.
5.
7.5
6.
7.
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0. 10. 0. 10. 0.
6.
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8.

FIELD NOTES FOR TRANSVERSE SECTIONS.

Stations.	Distances in feet.	Left slope stake +or-	Distance from center.	Angle +or-	Center +or-	Angle +or-	Distance from center.	Right slope stake +or-	Area of Excavation.	Area of Embankment.	Mean area of Excavation.	Mean area of Embankment.	Cubic yards of Excavation.	Cubic yards of Embankment.
0	0	0	10.	0	0	0	10.	0	0					
M. S.		+4.	16.	+5.	+6.	+8.	25.	+10.	200.					
1	100	+8.	22.	+10.	+12.	+16.	40.	+20.	550.		225.		833.33	
M. S.		+6.5	19.75	+8.	+9.5	+12.	32.5	+15.	369.					
2	100	+5.	17.5	+6.	+7.	+8.	25.	+10.	222.5		374.75		1387.96	
M. S.		+2.5	13.75	+3.	+4.5	+6.	22.	+8.	131.62					
3	100	0	10.	0	+2.	+4.	19.	+6.	58.		134.5		498.14	
M. S.		—3.	14.5	—2.5	+1.	+3.5	18.25	+5.5	38.34		*			
4	100	—6.	19.	—5.	--0	+3.	17.5	+5.	26.25	47.5	39.60	15.83	146.66	58.62
M. S.		—6.	19.	—5.5	—1.	+1.5	13.75	+2.5		59.8				
5	100	—6.	19.	--6.	--2.	0	10.	0		77.	8.75	60.61	32.40	224.48
M. S.		—7.	20.5	—7.	—5.	—4.	16.	—4.		153.75				
6	100	—8.	22.	—8.	—8.	—8.	22.	—8.		256.		158.0		585.18
M. S.		—4.	16.	—4.	—4.	--4.	16.	—4.		104.				
7	100	0	10.	0	0	0	10.	0		0		112.0		414.81

FACTORS.

EXCAVATION.

STATION 0. AREAS.

0.——0.——0. = 000.

MIDDLE SECTION.

16. × 5. = 80.
20. × 6. =120.
25. × 8. =200.

400.÷2.=200.

STATION 1.

22. × 10. =220.
20. × 12. =240.
40. × 16. =640.

1100.÷2.=550.

MIDDLE SECTION.

19.75 × 8. =158.
9.50 × 20. =190.
32.50 × 12. =390.

738.÷2.=369.

STATION 2.

17.50 × 6. =105.
20. × 7. =140.
25. × 8. =200.

445.÷2.=222.5.

MIDDLE SECTION.

13.75 × 3. = 41.25
20. × 4.5= 90.
22. × 6. =132.

263.25.÷2.=131.62.

STATION 3.

20. × 2. = 40.
19. × 4. = 76.

116.÷2.= 58.

MIDDLE SECTION.

12.8 × 1. = 12.80
18.25 × 3.5= 63.88

76.68.÷2.= 38.34.

STATION 4.

17.5 × 3. = 52.5 ÷2.= 26.25.

STATION 5.

——————————0.

EMBANKMENT.

STATION 4. AREAS.

19. × 5. = 95.÷2.= 47.5.

MIDDLE SECTION.

19. × 5.5=104.5
15. × 1. = 15.

119.5÷2.= 59.75.

STATION 5.

19. × 6. =114.
20. × 2. = 40.

154.÷2.= 77.

MIDDLE SECTION.

20.5 × 7. =143.5
20. × 5. =100.
16. × 4. = 64.

307.5÷2.=153.75.

STATION 6.

22. × 8. =176.
20. × 8. =160.
22. × 8. =176.

512.÷2.=256.

MIDDLE SECTION.

16. × 4. = 64.
20. × 4. = 80.
16. × 4. = 64.

208.÷2=104.

STATION 7.

0.——————0.——————0.

The cubic yards between station 0 and station 1 according to the method of adding the end areas and taking one-half for the mean area - - - - = 1018.51 c. yds. } c. yds.
By 2d (or Prismoidal method)= 833.33 " } 185.18

" 1st method	between	station	1 and 2	= 1430.55	"	}	42.59
" 2d "	"	"	1 and 2	1387.96	"	}	
" 1st "	"	"	2 and 3	519.44	"	}	21.30
" 2d "	"	"	2 and 3	498.14	"	}	
" 1st "	"	"	3 and 4	156.01	"	}	9.35
" 2d "	"	"	3 and 4	146.66	"	}	
" 1st "	"	"	4 and 5	48.59	"	}	16.19
" 2d "	"	"	4 and 5	32.40	"	}	

Error on 500 lineal feet of excavation - - =274.61

There are other methods which approximate nearer than the averaging method. For instance, taking $\frac{1}{2}\frac{1}{4}$ths of the difference between the end areas, (or the difference 0×0.46) and adding it to the lesser end area for the mean.

This method approximates nearer the true quantity. The principal discrepancy occurs where the embankment assumes the wedge or pryamidal form.—

By 3d method	between	station	0 and 1	937.03	cubic yards.		
" 2d "	(or Prismoidal)	0 and 1	833.33	+	103.70		
" 3d "	between	station	1 and 2	1382.03	—	5.93	
" 2d "	"	"	1 and 2	1387.96			
" 3d "	"	"	2 and 3	495.08	—	3.06	
" 2d "	"	"	2 and 3	498.14			
" 3d "	"	"	3 and 4	151.31	—	4.65	
" 2d "	"	"	3 and 4	146.66			
" 3d "	"	"	4 and 5	44.72	+	12.32	
" 2d "	"	"	4 and 5	32.40			

Error on 500 lineal feet of excavation - 102.38

Another method is to multiply $\frac{1}{6}$ of the distance between transverse sections, by the sum of the end areas, added to four times half their sum ; and dividing by 27 for the cubic yards.

The results are the same as by the first method except between stations 0 and 1.

EXPLANATION OF THE FOLLOWING TABLES.

The tables are calculated for a distance of 100 feet between transverse sections.

In the left hand column are given the areas in feet. To obtain the cubic yards for areas, without decimals, look in the second column under the head of 0, and opposite the given area, find the cubic yards.

EXAMPLE.—Required the number of cubic yards for an area of 190 feet. In the second column, under the head of 0, and opposite 190 in the first column, find 703.70 cubic yards.

To obtain the cubic yards for a less distance than 100 feet, multiply the cubic yards found in the tables by the given distance, and point off the fractional parts of 100 feet.

If the area has decimal parts, pass the eye to the right, opposite the area of the whole number, and under the head of such decimal will be found the number of yards.

EXAMPLE.—Required the cubic yards for an area of 105.4 feet. In the sixth column, under the head of 40, and opposite 105 in the first column, are given 390.37 cubic yards.

If the yards for an area greater than 354.90, and not exceeding 3549 feet, are required, the decimal point of the area given in the tables, and that of the cubic yards, being removed one figure to the right, will give the required yards. If there are decimal parts, add the cubic yards found opposite 0 in the first column, under the head of such decimal.

EXAMPLE.—Required the cubic yards for an area of 1975 feet; remove the decimal point one figure to the left, and find the yards for an area of 197.5 feet = 731.48, then remove the decimal point one figure to the right and you have 7314.8 cubic yards. If there is a decimal, add the cubic yards found for such decimal.

Or, to obtain the cubic yards for an area exceeding 3549 feet, take one half of the area, and seek the corresponding yards in tables and multiply the same by 2.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	0.00	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33
1	3.70	4.07	4.45	4.81	5.19	5.56	5.93	6.30	6.67	7.04
2	7.41	7.78	8.15	8.52	8.89	9.26	9.63	10.00	10.37	10.74
3	11.11	11.48	11·85	12.22	12.59	12.96	13.33	13.70	14.07	14.44
4	14.82	15.19	15.56	15.93	16.30	16.67	17.04	17.41	17.78	18.15
5	18.52	18.89	19.26	19.63	20.00	20.37	20.74	21.11	21.48	21.85
6	22.22	22.59	22.96	23.33	23.70	24.07	24.44	24.82	25.19	25.56
7	25.93	26.30	26.67	27.04	27.41	27.78	28.15	28.52	28.89	29.26
8	29.63	30.00	30.37	30.74	31.11	31.48	31.85	32.22	32.59	32.96
9	33.33	33.70	34.07	34.44	34.82	35.19	35.56	35.93	36.30	36.67
10	37.04	37.41	37.78	38.15	38.52	38.89	39.26	39.63	40.00	40.37
11	40 74	41.11	41.48	41.85	42.22	42.59	42.96	43.33	43.70	44.07
12	44.44	44.82	45.19	45.56	45.93	46.30	46.67	47.04	47.41	47.78
13	48.15	48.52	48.89	49.26	49.63	50.00	50.37	50.74	51.11	51.48
14	51 85	52.22	52.59	52.96	53.33	53.70	54.07	54.44	54.82	55.19
15	55.56	55.93	56.30	56.67	57.04	57.41	57.78	58.15	58.52	58.89
16	59.26	59.63	60.00	60.37	60.74	61.11	61.48	61.85	62.22	62.59
17	62.96	63.33	63.70	64.07	64.44	64.82	65.19	65.56	65.93	66.30
18	66.67	67.04	67.41	67.78	68.15	68.52	68.89	69.26	69.63	70.00
19	70.37	70.74	71.11	71.48	71.85	72.22	72.59	72.96	73.33	73 70
20	74.07	74.44	74.82	75.19	75.56	75.93	76.30	76.67	77.04	77.41
21	77.78	78.15	78.52	78.89	79.26	79.63	80.00	80.37	80.74	81.11
22	81.48	81.85	82.22	82.59	82.96	83.33	83.70	84.07	84.44	84.82
23	85.19	85.56	85.93	86.30	86.67	87.04	87.41	87.78	88.15	88.52
24	88.89	89.26	89.63	90.00	90.37	90.74	91.11	91.48	91.85	92.22
25	92.59	92.96	93.33	93.70	94.07	94.44	94.82	95.19	95.56	95.93
26	96.30	96.67	97.04	97.41	97.78	98.15	98.52	98.89	99.26	99 63
27	100.00	100.37	100.74	101.11	101.48	101.85	102.22	102.59	102.96	103.33
28	103.70	104.07	104.44	104.82	105.19	105.56	105.93	106.30	106.67	107.04
29	107.41	107.78	108.15	108.52	108.89	109.26	109.63	110.00	110.37	110.74
30	111.11	111.48	111.85	112.22	112.59	112.96	113.33	113.70	114.07	114.44
31	114.81	115.18	115.56	115.92	116.29	116.67	117.03	117.40	117.77	118.15
32	118.52	118.89	119.26	119.63	120.00	120.37	120.74	121.11	121.48	121.85
33	122.22	122.59	122.96	123.33	123.70	124.07	124.44	124.81	125.18	125.55
34	125.92	126.30	126.66	127.03	127.40	127.77	128.14	128.51	128.88	129.26
35	129.63	130.00	130.37	130.74	131.11	131.48	131.85	132.22	132.59	132.96
36	133.33	133.70	134.07	134.44	134.81	135.18	135.55	135.92	136.29	136.67
37	137.04	137.41	137.78	138.15	138.52	138.89	139.26	139.63	140.00	140.37
38	140.74	141.11	141.48	141.85	142.22	142.59	142.96	143.33	143.70	144.07
39	144.44	144.81	145.18	145.55	145.92	146.29	146.66	147.03	147.40	147.78
40	148.15	148.52	148.89	149.26	149.63	150.00	150.37	150.74	151.11	151.48
41	151.85	152.22	152.59	152.96	153.33	153.70	154.07	154.44	154.81	155.18
42	155.55	155.92	156.29	156.66	157.03	157.40	157.77	158.14	158.51	158.89
43	159.26	159.63	160.00	160.37	160.74	161.11	161.48	161.85	162.22	162.59
44	162.96	163.33	163.70	164.07	164.44	164.81	165.18	165.55	165.92	166.30
45	166.67	167 04	167.41	167.78	168.15	168.52	168.89	169.26	169.63	170.00
46	170.37	170.74	171.11	171.48	171.85	172.22	172.59	172.96	173.33	173.70
47	174.07	174.44	174.81	175.18	175.55	175.92	176.29	176.66	177.03	177.41
48	177.78	178.15	178.52	178.89	179.26	179.63	180.00	180.37	180.74	181.11
49	181.48	181.85	182.22	182.59	182.96	183.33	183.70	184.07	184.44	184.81
50	185.18	185.55	185 92	186.29	186.66	187.03	187.40	187.77	188.14	188.52
51	188.89	189.26	189.63	190.00	190.37	190.74	191.11	191.48	191.85	192.22
52	192.59	192.96	193.33	193.70	194.07	194.44	194.81	195.18	195.55	195.93
53	196.30	196.67	197.04	197.41	197.78	198.15	198.52	198.89	199.26	199.63
54	200.00	200.37	200.74	201.11	201.48	201.85	202.22	202.59	202.96	203.33
55	203.70	204.07	204.44	204.81	205.18	205.55	205.92	206.29	206.66	207.03
56	207.41	207.78	208.15	208.52	208.89	209.26	209.63	210.00	210.37	210.74
57	211.11	211.48	211.85	212.22	212.59	212.96	213.33	213.70	214.07	214.44
58	214.81	215.18	215.55	215.92	216.29	216.66	217.03	217.40	217.77	218.15
59	218.52	218.89	219.26	219.63	220.00	220.37	220.74	221.11	221.48	221.85

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
60	222.22	222.59	222.96	223.33	223.70	224.07	224.44	224.81	225.18	225.55
61	225.92	226.29	226.66	227.03	227.40	227.77	228.14	228.51	228.88	229.26
62	229.63	230.00	230.37	230.74	231.11	231.48	231.85	232.22	232.59	232.96
63	233.33	233.70	234.07	234.44	234.81	235.18	235.55	235.92	236.29	236.67
64	237.04	237.41	237.78	238.15	238.52	238.89	239.26	239.63	240.00	240.37
65	240.74	241.11	241.48	241.85	242.22	242.59	242.96	243.33	243.70	244.07
66	244.44	244.81	245.18	245.55	245.92	246.30	246.67	247.04	247.41	247.78
67	248.15	248.52	248.89	249.26	249.63	250.00	250.37	250.74	251.11	251.48
68	251.85	252.22	252.59	252.96	253.33	253.70	254.07	254.44	254.81	255.18
69	255.56	255.93	256.30	256.67	257.04	257.41	257.78	258.15	258.52	258.89
70	259.26	259.63	260.00	260.37	260.74	261.11	261.48	261.85	262.22	262.59
71	262.96	263.33	263.70	264.07	264.44	264.81	265.18	265.55	265.92	266.30
72	266.67	267.04	267.41	267.78	268.15	268.52	268.89	269.26	269.63	270.00
73	270.37	270.74	271.11	271.48	271.85	272.22	272.59	272.96	273.33	273.70
74	274.07	274.44	274.81	275.18	275.55	275.92	276.29	276.66	277.04	277.41
75	277.78	278.15	278.52	278.89	279.26	279.63	280.00	280.37	280.74	281.11
76	281.48	281.85	282.22	282.59	282.96	283.33	283.70	284.07	284.44	284.81
77	285.18	285.56	285.93	286.30	286.67	287.04	287.41	287.78	288.15	288.52
78	288.89	289.26	289.63	290.00	290.37	290.74	291.11	291.48	291.85	292.22
79	292.59	292.96	293.33	293.70	294.07	294.44	294.81	295.18	295.55	295.93
80	296.30	296.67	297.04	297.41	297.78	298.15	298.52	298.89	299.26	299.63
81	300.00	300.37	300.74	301.11	301.48	301.85	302.22	302.59	302.96	303.33
82	303.70	304.07	304.44	304.81	305.18	305.55	305.92	306.29	306.66	307.03
83	307.41	307.78	308.15	308.52	308.89	309.26	309.63	310.00	310.37	310.74
84	311.11	311.48	311.85	312.22	312.59	312.96	313.33	313.70	314.07	314.44
85	314.81	315.19	315.56	315.93	316.30	316.67	317.04	317.41	317.78	318.15
86	318.52	318.89	319.26	319.63	320.00	320.37	320.74	321.11	321.48	321.85
87	322.22	322.59	322.96	323.33	323.70	324.07	324.44	324.81	325.18	325 55
88	325.92	326.30	326.67	327.04	327.41	327.78	328.15	328.52	328.89	329.26
89	329.63	330.00	330.37	330.74	331.11	331.48	331.85	332.22	332.59	332.96
90	333.33	333.70	334.07	334.44	334.81	335.18	335.55	335.92	336.29	336.67
91	337.04	337.41	337.78	338.15	338.52	338.89	339.25	339.62	339.99	340.37
92	340.74	341.11	341.48	341.85	342.22	342.59	342.96	343.33	343.70	344.07
93	344.44	344.81	345.18	345.56	345.93	346.30	346.67	347.03	347.40	347.78
94	348.15	348.52	348.89	349.26	349.63	350.00	350.37	350.74	351.11	351.48
95	351.85	352.22	352.59	352.96	353.33	353.70	354.07	354.44	354.81	355.18
96	355.55	355.93	356.30	356.67	357.04	357.41	357.78	358.15	358.52	358.89
97	359.26	359.63	360.00	360.37	360.74	361.11	361.48	361.85	362.22	362.59
98	362.96	363.33	363.70	364.07	364.44	364.81	365.18	365.55	365.93	366.30
99	366.67	367.04	367.41	367.78	368.15	368.52	368.89	369.26	369.63	370.00
100	370.37	370.74	371.11	371.48	371.85	372.22	372.59	372.96	373.33	373.70
101	374.07	374.44	374.81	375.18	375.55	375.92	376.29	376.67	377.04	377.41
102	377.78	378.15	378.52	378.89	379.26	379.63	380.00	380.37	380.74	381.11
103	381.48	381.85	382.22	382.59	382.96	383.33	383.70	384.07	384.44	384 81
104	385.18	385.55	385.92	386.29	386.67	387.04	387.41	387.78	388.15	388.52
105	388.89	389.26	389.63	390.00	390.37	390.74	391.11	391.48	391.85	392.22
106	392.59	392.96	393.33	393.70	394.07	594.44	394.81	395.18	395.55	395.92
107	396.30	396.67	397.04	397.41	397.78	398.15	398.52	398.89	399.26	399.63
108	400.00	400.37	400.74	401.11	401.48	401.85	402.22	402.59	402.96	403.33
109	403.70	404.07	404.44	404.81	405.18	405.55	405.92	406.29	406.67	407.04
110	407.41	407.78	408.15	408.52	408.89	409.26	409.63	410.00	410.37	410.74
111	411.11	411.48	411.85	412.22	412.59	412.96	413.33	413.70	414.07	414.44
112	414.81	415.18	415.55	415.92	416.29	416.67	417.04	417.41	417.78	418.15
113	418.52	418.89	419.26	419.63	420.00	420.37	420.74	421.11	421.48	421.85
114	422.22	422.59	422.96	423.33	423.70	424.07	424.44	424.81	425.18	425.56
115	425.93	426.30	426.67	427.04	427.41	427.78	428.15	428.52	428.89	429.26
116	429.63	430.00	430.37	430.74	431.11	431.48	431.85	432.22	432.59	432.96
117	433.33	433.70	434.07	434.44	434.81	435.18	435.55	435.92	436.29	436.67
118	437.04	437.41	437.78	438.15	438.52	438.89	439.26	439.63	440.00	440.37
119	440.74	441.11	441.48	441.85	442.22	442.59	442.96	443.33	443.70	444.07

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
120	444.44	444.81	445.18	445.55	445.92	446.29	446.67	447 04	447.41	447.78
121	448.15	448.52	448.89	449.26	449.63	450.00	450.37	450.74	451.11	451.48
122	451.85	452.22	452.59	452.96	453.33	453.70	454.07	454.44	454.81	455.18
123	455.55	455.92	456.29	456.67	457.04	457.41	457.78	458.15	458.52	458.89
124	459.26	459.63	460.00	460.37	460.74	461.11	461.48	461.85	462.22	462.59
125	462.96	463.33	463.70	464.07	464.44	464.81	465.18	465.55	465.93	466.30
126	466.67	467.04	467.41	467.78	468.15	468.52	468.89	469.26	469.63	470.00
127	470.37	470.74	471.11	471.48	471.85	472.22	472.59	472.96	473.33	473.70
128	474.07	474.44	474.81	475.18	475.56	475.93	476.30	476.67	477.04	477.41
129	477.78	478.15	478.52	478.89	479.26	479.63	480.00	480.37	480.74	481.11
130	481.48	481.85	482.22	482.59	482.96	483.33	483.70	484.07	484.44	484.81
131	485.18	485.55	485.92	486.29	486.67	487.04	487.41	487.78	488.15	488.52
132	488.89	489.26	489.63	490.00	490.37	490.74	491.11	491.48	491.85	492.22
133	492.59	492.96	493.33	493.70	494.07	494.44	494.81	495.19	495.56	495.93
134	496.30	496.67	497.04	497.41	497.78	498.15	498.52	498.89	499.26	499.63
135	500.00	500.37	500.74	501.11	501.48	501.85	502.22	502.59	502.96	503.33
136	503.70	504.07	504.44	504.81	505.18	505.56	505.93	506.30	506.67	507.04
137	507.41	507.78	508.15	508.52	508.89	509.26	509.63	510.00	510.37	510.74
138	511.11	511.48	511.85	512.22	512.59	512.96	513.33	513.70	514.07	514.44
139	514.81	515.18	515.55	515.92	516.29	516.67	517.04	517.41	517.78	518.15
140	518.52	518.89	519.26	519.63	520.00	520.37	520.74	521.11	521.48	521.85
141	522.22	522.59	522.96	523.33	523.70	524.07	524.44	524.81	525.19	525.56
142	525.93	526.30	526.67	527.04	527.41	527.78	528.15	528.52	528.89	529.26
143	529.63	530.00	530.37	530.74	531.11	531.48	531.85	532.22	532.59	532.94
144	533.33	533.70	534.07	534.44	534.81	535.18	535.56	535.93	536.30	536.67
145	537.04	537.41	537.78	538.15	538.52	538.89	539.26	539.63	540.00	540.37
146	540.74	541.11	541.48	541.85	542.22	542.59	542.96	543.33	543.70	544.07
147	544.44	544.81	545.18	545.56	545.93	546.30	546.67	547.04	547.41	547.78
148	548.15	548.52	548.89	549.26	549.63	550.00	550.37	550.74	551.11	551.48
149	551.85	552.22	552.59	552.96	553.33	553.70	554.07	554.44	554.81	555.18
150	555.55	555.93	556.30	556.67	557.04	557.41	557.78	558.15	558.52	558.89
151	559.26	559.63	560.00	560.37	560.74	561.11	561.48	561.85	562.22	562.59
152	562.96	563.33	563.70	564.07	564.44	564.81	565.18	565.56	565.93	566.30
153	566.67	567.04	567.41	567.78	568.15	568.52	568.89	569.26	569.63	570.00
154	570.37	570.74	571.11	571.48	571.85	572.22	572.59	572.96	573.33	573.70
155	574.07	574.44	574.81	575.18	575.56	575.93	576.30	576.67	577.04	577.41
156	577.78	578.15	578.52	578.89	579.26	579.63	580.00	580.37	580.74	581.11
157	581.48	581.85	582.22	582.59	582.96	583.33	583.70	584.07	584.44	584.81
158	585.18	585.55	585.92	586.29	586.66	587.04	587.41	587.78	588.15	588.52
159	588.89	589.26	589.63	590.00	590.37	590.74	591.11	591.48	591.85	592.22
160	592.59	592.96	593.33	593.70	594.07	594.44	594.81	595.18	595.55	595.92
161	596.29	596.67	597.04	597.41	597.78	598.15	598.52	598.89	599.26	599.63
162	600.00	600.37	600.74	601.11	601.48	601.85	602.22	602.59	602.96	603.33
163	603.70	604.07	604.44	604.81	605.18	605.55	605.92	606.30	606.67	607.04
164	607.41	607.78	608.15	608.52	608.89	609.26	609.63	610.00	610.37	610.74
165	611.11	611.48	611.85	612.22	612.59	612.96	613.33	613.70	614.07	614.44
166	614.81	615.18	615.55	615.92	616.29	616.67	617.04	617.41	617.78	618.15
167	618.52	618.89	619.26	619.63	620.00	620.37	620.74	621.11	621.48	621.85
168	622.22	622.59	622.96	623.33	623.70	624.07	624.44	624.81	625.18	625.56
169	625.93	626.30	626.67	627.04	627.41	627.78	628.15	628.52	628.89	629.26
170	629.63	630.00	630.37	630.74	631.11	631.48	631.85	632.22	632.59	632.96
171	633.33	633.70	634.07	634.44	634.81	635.18	635.55	635.92	636.29	636.66
172	637.04	637.40	637.77	638.14	638.51	638.88	639.25	639.62	639.99	640.37
173	640.74	641.11	641.48	641.85	642.22	642.59	642.96	643.33	643.70	644.07
174	644.44	644.81	645.18	645.55	645.92	646.29	646.66	647.03	647.41	647.78
175	648.15	648.52	648.89	649 26	649.63	650.00	650.37	650.74	651.11	651.48
176	651.85	652.22	652.59	652.96	653.33	653.70	654.07	654.44	654.81	655.18
177	655.56	655.93	656.30	656.67	657.04	657.41	657.78	658.15	658.52	658.89
178	659.26	659.63	660.00	660.37	660.74	661.11	661.48	661.85	662.22	662.59
179	662.96	663.33	663.70	664.07	664.44	664.81	665.18	665.55	665.92	666.29

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
180	666.67	667.04	667.41	667.78	668.15	668.52	668.89	669.26	669.63	670.00
181	670.37	670.74	671.11	671.48	671.85	672.22	672.59	672.96	673.33	673.70
182	674.07	674.44	674.81	675.18	675.55	675.93	676.30	676.67	677.04	677.41
183	677.78	678.15	678.52	678.89	679.26	679.63	680.00	680.37	680.74	681.11
184	681.48	681.85	682.22	682.59	682.96	683.33	684.70	684.07	684.44	684.81
185	685.18	685.56	685.93	686.30	686.67	687.04	687.41	687.78	688.15	688.52
186	688.89	689.26	689.63	690.00	690.37	690.74	691.11	691.48	691.85	692.22
187	692.59	692.96	693.33	693.70	694.07	694.44	694.81	695.18	695.55	695.92
188	696.30	696.67	697.04	697.41	697.78	698.15	698.52	698.89	699.26	699.63
189	700.00	700.37	700.74	701.11	701.48	701.85	702.22	702.59	702.96	703.33
190	703.70	704.07	704.44	704.81	705.18	705.55	705.92	706.29	706.66	707.03
191	707.40	707.77	708.14	708.51	708.89	709.26	709.63	710.00	710.37	710.74
192	711.11	711.48	711.85	712 22	712.59	712.96	713.33	713.70	714.07	714.44
193	714.81	715.18	715.55	715.92	716.29	716.67	717.04	717.41	717.78	718.15
194	718.52	718.89	719.26	719.63	720.00	720.37	720.74	721.11	721.48	721.85
195	722.22	722.59	722.96	723.33	723.70	724.07	724.44	724.81	725.18	725.55
196	725.92	726.29	726.66	727.03	727.40	727.77	728.14	728.51	728.88	729.25
197	729.63	730.00	730.37	730.74	731.11	731.48	731.85	732.22	732.59	732.96
198	733.33	733.70	734.07	734.44	734.81	735.18	735.55	735.93	736.30	736.67
199	737.04	737.41	737.78	738.15	738.52	738.89	739.26	739.63	740.00	740.37
200	740.74	741.11	741.48	741.85	742.22	742.59	742.96	743.33	743.70	744.07
201	744.44	744.81	745.18	745.55	745.93	746.30	746.67	747.04	747.41	747.78
202	748.15	748.52	748.89	749.26	749.63	750.00	750.37	750.74	751.11	751.48
203	751.85	752.22	752.59	752.96	753.33	753.70	754.07	754.44	754.81	755.18
204	755.55	755.93	756.30	756.67	757.04	757.41	757.78	758.15	758.52	758.89
205	759.26	759.63	760.00	760.37	760.74	761.11	761.48	761.85	762.22	762.59
206	762.96	763.33	763.70	764.07	764.44	764.81	765.18	765.55	765.93	766.30
207	766.66	767.04	767.41	767.78	768.15	768.52	768 89	769.26	769.63	770.00
208	770.37	770.74	771.11	771.48	771.85	772.22	772.59	772.96	773.33	773.70
209	774.07	774.44	774.81	775.18	775.55	775.93	776.30	776.66	777.04	777.41
210	777.78	778.15	778.52	778.89	779.26	779.63	780.00	780.37	780.74	781.11
211	781.48	781.85	782.22	782.59	782.96	783.33	783.70	784.07	784.44	784.81
212	785.18	785.55	785.93	786.30	786.66	787.04	787.41	787.78	788.15	788.52
213	788.89	789.26	789.63	790.00	790.37	790.74	791.11	791.48	791.85	792.22
214	792.59	792.96	793.33	793.70	794.07	794.44	794.81	795.18	795.55	795.93
215	796.30	796.66	797.04	797.41	797.78	798.15	798.52	798.89	799.26	799.63
216	800.00	800.37	800.74	801.11	801.48	801.85	802.22	802.59	802.96	803.33
217	803.70	804.07	804.44	804.81	805.18	805.55	805.93	806.30	806.66	807.04
218	807.41	807.78	808.15	808.52	808.89	809.26	809.63	810.00	810.37	810.74
219	811.11	811.48	811.85	812.22	812.59	812.96	813.33	813.70	814.07	814.44
220	814.81	815.18	815.55	815.93	816.30	816.66	817.04	817.41	817.78	818.15
221	818.52	818.89	819.26	819.63	820.00	820.37	820.74	821.11	821.48	821.85
222	822.22	822.59	822.96	823.33	823.70	824.07	824.44	824.81	825.18	825.55
223	825.93	826.30	826.66	827.04	827.41	827.78	828.15	828.52	828.89	829.26
224	829.63	830.00	830.37	830.74	831.11	831.48	831.85	832.22	832.59	832.96
225	833.33	833.70	834.07	834.44	834.81	835.18	835 55	835.93	836.30	836.66
226	837.04	837.41	837.78	838 15	838.52	838.89	839.26	839.63	840.00	840.37
227	840.74	841.11	841.48	841.85	842.22	842.59	842.96	843.33	843.70	844.07
228	844.44	844.81	845.18	845.55	845.93	846.30	846.66	847.04	847.41	847.78
229	848.15	848.52	848.89	849.26	849.63	850.00	850.37	850.74	851.11	851.48
230	851.85	852.22	852.59	852.96	853.33	853.70	854.07	854.44	854.81	855.18
231	855.55	855.93	856.30	856.66	857.04	857.41	857.78	858.15	858.52	858.89
232	859.26	859.63	860.00	860.37	860.74	861.11	861.48	861.85	862.22	862.59
233	862.96	863.33	863.70	864.07	864.44	864.81	865.18	865.55	865.93	866.30
234	866.66	867.04	867.41	867.78	868.15	868.52	868.89	869.26	869.63	870.00
235	870.37	870.74	871.11	871.48	871.85	872.22	872.59	872.96	873.33	873.70
236	874.07	874.44	874.81	875.18	875.55	875.93	876.30	876.66	877.04	877.41
237	877.78	878.15	878.52	878.89	879.26	879.63	880.00	880.37	880.74	881.11
238	881.48	881.85	882.22	882.59	882.96	883.33	883 70	884.07	884.44	884.81
239	885.18	885.55	885.93	886.30	886.66	887.04	887.41	887.78	888.15	888.52

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
240	888.88	889.26	889.63	890.00	890.37	890.74	891.11	891.48	891.85	892.22
241	892.59	892.96	893.33	893.70	894.07	894.44	894.81	895.18	895.55	895.93
242	896.30	896.66	897.04	897.41	897.78	898.15	898.52	898.88	899.26	899.63
243	900.00	900.37	900.74	901.11	901.48	901.85	902.22	902.59	902.96	903.33
244	903.70	904.07	904.44	904.81	905.18	905.55	905.93	906.30	906.66	907.04
245	907.41	907.78	908.15	908.52	908.88	909.26	909.63	910.00	910.37	910.74
246	911.11	911.48	911.85	912.22	912.59	912.96	913.33	913.70	914.07	914.44
247	914.81	915.18	915.55	915.93	916.30	916.66	917.04	917.41	917.78	918.15
248	918.52	918.88	919.26	919.63	920.00	920.37	920.74	921.11	921.48	921.85
249	922.22	922.59	922.96	923.33	923.70	924.07	924.44	924.81	925.18	925.55
250	925.92	926.30	926.66	927.04	927.41	927.78	928.15	928.52	928.88	929.26
251	929.63	930.00	930.37	930.74	931.11	931.48	931.85	932.22	932.59	932.96
252	933.33	933.70	934.07	934.44	934.81	935.18	935.55	935.92	936.30	936.66
253	937.04	937.41	937.78	938.15	938.52	938.88	939.26	939.63	940.00	940.37
254	940.74	941.11	941.48	941.85	942.22	942.59	942.96	943.33	943.70	944.07
255	944.44	944.81	945.18	945.55	945.92	946.30	946.66	947.04	947.41	947.78
256	948.15	948.52	948.88	949.26	949.63	950.00	950.37	950.74	951.11	951.48
257	951.85	952.22	952.59	952.96	953.33	953.70	954.07	954.44	954.81	955.18
258	955.55	955.92	956.30	956.66	957.04	957.41	957.78	958.15	958.52	958.88
259	959.26	959.63	960.00	960.37	960.74	961.11	961.48	961.85	962.22	962.59
260	962.96	963.33	963.70	964.07	964.44	964.81	965.18	965.55	965.92	266.30
261	966.66	967.04	967.41	967.78	968.15	968.52	968.88	969.26	969.63	970.00
262	970.37	970.74	971.11	971.48	971.85	972.22	972.59	972.96	973.33	973.70
263	974.07	974.44	974.81	975.18	975.55	975.92	976.30	976.66	977.04	977.41
264	977.78	978.15	978.52	978.88	979.26	979.63	980.00	980.37	980.74	981.11
265	981.48	981.85	982.22	982.59	982.96	983.33	983.70	984.07	984.44	984.81
266	985.18	985.55	985.92	986.30	986.66	987.04	987.41	987.78	988.15	988.52
267	988.88	989.26	989.63	990.00	990.37	990.74	991.11	991.48	991.85	992.22
268	992.59	992.96	993.33	993.70	994.07	994.44	994.81	995.18	995.55	995.92
269	996.30	996.66	997.04	997.41	997.78	998.15	998.52	998.88	999.26	999.63
270	1000.00	1000.37	1000.74	1001.11	1001.48	1001.85	1002.22	1002.59	1002.96	1003.33
271	1003.70	1004.07	1004.44	1004.81	1005.18	1005.55	1005.92	1006.30	1006.66	1007.04
272	1007.41	1007.78	1008.15	1008.52	1008.88	1009.26	1009.63	1010.00	1010.37	1010.74
273	1011.11	1011.48	1011.85	1012.22	1012.59	1012.96	1013.33	1013.70	1014.07	1014.44
274	1014.81	1015.18	1015.55	1015.92	1016.30	1016.66	1017.04	1017.41	1017.78	1018.15
275	1018.52	1018.88	1019.26	1019.63	1020.00	1020.37	1020.74	1021.11	1021.48	1021.85
276	1022.22	1022.59	1022.96	1023.33	1023.70	1024.07	1024.44	1024.81	1025.18	1025.55
277	1025.92	1026.30	1026.66	1027.04	1027.41	1027.78	1028.15	1028.52	1028.88	1029.26
278	1029.63	1030.00	1030.37	1030.74	1031.11	1031.48	1031.85	1032.22	1032.59	1032.96
279	1033.33	1033.70	1034.07	1034.44	1034.81	1035.18	1035.55	1035.92	1036.30	1036.66
280	1037.04	1037.41	1037.78	1038.15	1038.52	1038.88	1039.26	1039.63	1040.00	1040.37
281	1040.74	1041.11	1041.48	1041.85	1042.22	1042.59	1042.96	1043.33	1043.70	1044.07
282	1044.44	1044.81	1045.18	1045.55	1045.92	1046.30	1046.66	1047.04	1047.41	1047.78
283	1048.15	1048.52	1048.88	1049.26	1049.63	1050.00	1050.37	1050.74	1051.11	1051.48
284	1051.85	1052.22	1052.59	1052.96	1053.33	1053.70	1054.07	1054.44	1054.81	1055.18
285	1055.55	1055.92	1056.30	1056.66	1057.04	1057.41	1057.78	1058.15	1058.52	1058.88
286	1059.26	1059.63	1060.00	1060.37	1060.74	1061.11	1061.48	1061.85	1062.22	1062.59
287	1062.96	1063.33	1063.70	1064.07	1064.44	1064.81	1065.18	1065.55	1065.92	1066.30
288	1066.66	1067.04	1067.41	1067.78	1068.15	1068.52	1068.88	1069.26	1069.63	1070.00
289	1070.37	1070.74	1071.11	1071.48	1071.85	1072.22	1072.59	1072.96	1073.33	1073.70
290	1074.07	1074.44	1074.81	1075.18	1075.55	1075.92	1076.30	1076.66	1077.04	1077.41
291	1077.78	1078.15	1078.52	1078.88	1079.26	1079.63	1080.00	1080.37	1080.74	1081.11
292	1081.48	1081.85	1082.22	1082.59	1082.96	1083.33	1083.70	1084.07	1084.44	1084.81
293	1085.18	1085.55	1085.92	1086.30	1086.66	1087.04	1087.41	1087.78	1088.15	1088.52
294	1088.88	1089.26	1089.63	1090.00	1090.37	1090.74	1091.11	1091.48	1091.85	1092.22
295	1092.59	1092.96	1093.33	1093.70	1094.07	1094.44	1094.81	1095.18	1095.55	1095.92
296	1096.30	1096.66	1097.04	1097.41	1097.78	1098.15	1098.52	1098.88	1099.26	1099.63
297	1100.00	1100.37	1100.74	1101.11	1101.48	1101.85	1102.22	1102.59	1102.96	1103.33
298	1103.70	1104.07	1104.44	1104.81	1105.18	1105.55	1105.92	1106.30	1106.66	1107.04
299	1107.41	1107.78	1108.15	1108.52	1108.88	1109.26	1109.63	1110.00	1110.37	1110.74

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
300	1111.11	1111.48	1111.85	1112.22	1112.59	1112.96	1113.33	1113.70	1114.07	1114.44
301	1114.82	1115.19	1115.56	1115.93	1116.30	1116.67	1117.04	1117.41	1117.78	1118.15
302	1118.52	1118.89	1119.26	1119.63	1120.00	1120.37	1120.74	1121.11	1121.48	1121.85
303	1122.22	1122.59	1122.96	1123.33	1123.70	1124.07	1124.44	1124.82	1125.19	1125.56
304	1125.93	1126.30	1126.67	1127.04	1127.41	1127.78	1128.15	1128.52	1128.89	1129.26
305	1129.63	1130.00	1130.37	1130.74	1131.11	1131.48	1131.85	1132.22	1132.59	1132.96
306	1133.33	1133.70	1134.07	1134.44	1134.82	1135.19	1135.56	1135.93	1136.30	1137.67
307	1137.04	1137.41	1137.78	1138.15	1138.52	1138.89	1139.26	1139.63	1140.00	1140.37
308	1140.74	1141.11	1141.48	1141.85	1142.22	1142.59	1142.96	1143.33	1143.70	1144.07
309	1144.44	1144.82	1145.19	1145.56	1145.93	1146.30	1146.67	1147.04	1147.41	1147.78
310	1148.15	1148.52	1148.89	1149.26	1149.63	1150.00	1150.37	1150.74	1151.11	1151.48
311	1151.85	1152.22	1152.59	1152.96	1153.33	1153.70	1154.07	1154.44	1154.82	1155.19
312	1155.56	1155.93	1156.30	1156.67	1157.04	1157.41	1157.78	1158.15	1158 52	1158.89
313	1159.26	1159.63	1160.00	1160.37	1160.74	1161.11	1161.48	1161.85	1162.22	1162.59
314	1162.96	1163.33	1163.70	1164.07	1164.44	1164.82	1165.19	1165.56	1165.93	1166.30
315	1166.67	1167.04	1167.41	1167.78	1168.15	1168.52	1168.89	1169.26	1169.63	1170.00
316	1170.37	1170.74	1171.11	1171.48	1171.85	1172.22	1172.59	1172.96	1173.33	1173.70
317	1174.07	1174.44	1174.82	1175.19	1175.56	1175.93	1176.30	1176.67	1177.04	1177.41
318	1177.78	1178.15	1178.52	1178.89	1179.26	1179.63	1180.00	1180.37	1180.74	1181 11
319	1181.48	1181.85	1182.22	1182.59	1182.96	1183.33	1183.70	1184.07	1184.44	1184.82
320	1185.19	1185.56	1185.93	1186.30	1186.67	1187.04	1187.41	1187.78	1188.15	1188.52
321	1188.89	1189.26	1189.63	1190.00	1190.37	1190.74	1191.11	1191.48	1191.85	1192.22
322	1192.59	1192.96	1193.33	1193.70	1194.07	1194.44	1194.82	1195.19	1195.56	1195.93
323	1196.30	1196.67	1197.04	1197.41	1197.78	1198.15	1198.52	1198.89	1199.26	1199.63
324	1200.00	1200.37	1200.74	1201.11	1201.48	1201.85	1202.22	1202.59	1202.96	1203.33
325	1203.70	1204.07	1204.44	1204.82	1205.19	1205.56	1205.93	1206.30	1206.67	1207.04
326	1207.41	1207.78	1208.15	1208.52	1208.89	1209.26	1209.63	1210.00	1210.37	1210.74
327	1211.11	1211.48	1211.85	1212.22	1212.59	1212.96	1213.33	1213.70	1214.07	1214.44
328	1214.82	1215.19	1215.56	1215.93	1216.30	1216.67	1217.04	1217.41	1217.78	1218.15
329	1218.52	1218.89	1219.26	1219.63	1220.00	1220.37	1220.74	1221.11	1221.48	1221.86
330	1222.22	1222.59	1222.96	1223.33	1223.70	1224.07	1224.44	1224.81	1225.18	1225.55
331	1225.93	1226.30	1226.67	1227.04	1227.41	1227.78	1228.15	1228.52	1228.89	1229.26
332	1229.63	1230.00	1230.37	1230.74	1231.11	1231.48	1231.85	1232.22	1232.59	1232.96
333	1233.33	1233.70	1234.07	1234.44	1234.82	1235.19	1235.56	1235.93	1236.30	1236.67
334	1237.04	1237.41	1237.78	1238.15	1238.52	1238.89	1239.26	1239.63	1240.00	1240.37
335	1240.74	1241.11	1241.48	1241.85	1242.22	1242.59	1242.96	1243.33	1243.70	1244.07
336	1244.44	1244.82	1245.19	1245.56	1245.93	1246.30	1246.67	1247.04	1247.41	1247.78
337	1248.15	1248.52	1248.89	1249.26	1249.63	1250.00	1250.37	1250.74	1251.11	1251.48
338	1251.85	1252.22	1252.59	1252.96	1253.33	1253.70	1254.07	1254.44	1254.82	1255.19
339	1255.56	1255.93	1256.30	1256.67	1257.04	1257.41	1257.73	1258.15	1258,52	1258.89
340	1259.26	1259.63	1260.00	1260.37	1260.74	1261.11	1261.48	1261.85	1262.22	1262.59
341	1262.96	1263.33	1263.70	1264.07	1264.44	1264.82	1265.19	1265.56	1265.93	1266.30
342	1266.67	1267.04	1267.41	1267.78	1268.15	1268.52	1268.89	1269.26	1269.63	1270.00
343	1270.37	1270.74	1271.11	1271.48	1271.85	1272.22	1272.59	1272.96	1273.33	1273.70
344	1274.07	1274.44	1274.82	1275.19	1275.56	1275.93	1276.30	1276.67	1277.04	1277.41
345	1277.78	1278.15	1278.52	1278.89	1279.26	1279.63	1280.00	1280.37	1280.74	1281.11
346	1281.48	1281.85	1282.22	1282.59	1282.96	1283.33	1283.70	1284.07	1284.44	1284.82
347	1285.19	1285.56	1285.93	1286.30	1286.67	1287.04	1287.41	1287.78	1288.15	1288.52
348	1288.89	1289.26	1289.63	1290.00	1290.37	1290.74	1291.11	1291.48	1291.85	1292.22
349	1292.59	1292.96	1293.33	1293.70	1294.07	1294.44	1294.82	1295.19	1295.56	1295.93
350	1296.30	1296.67	1297.04	1297.41	1297.78	1298.15	1298.52	1298.89	1299.26	1299.63
351	1300.00	1300.37	1300.74	1301.11	1301.48	1301.85	1302.22	1302.59	1302.96	1303 33
352	1303.70	1304.07	1304.44	1304.82	1305.19	1305.56	1305.93	1306.30	1306 67	1307.04
353	1307.41	1307.78	1308.15	1308.52	1308.89	1309.26	1309.63	1310.00	1310.37	1310.74
354	1311.11	1311.48	1311.85	1312.22	1312.59	1312.96	1313.33	1313.70	1314 07	1314.44
355	1314.82	1315.19	1315.56	1315.93	1316.30	1316.67	1317.04	1317.41	1317.78	1318.15
356	1318.52	1318.89	1319.26	1319.63	1320.00	1320.37	1320.74	1321.11	1321.48	1321.86
357	1322.22	1322.59	1322.96	1323.33	1323.70	1324.07	1324.44	1324.81	1325.18	1325.55
358	1325.93	1326.30	1326.67	1327.04	1327.41	1327.78	1328.15	1328.52	1328.89	1329.26
359	1329.63	1330.00	1330.37	1330.74	1331.11	1331.48	1331.85	1332.22	1332.59	1332.96

INSTRUCTIONS TO DIVISION AND ASSISTANT ENGINEERS RELATIVE TO FIELD NOTES ON SURVEYS FOR THE SOUTH PENNA. R. R. CO.

First—Enter the names of the Division Engineer, Senior Assistant Engineer in charge of the party, Assistant Engineer at Transit Instrument, Assistant Engineer at Leveling Instrument, Rodmen, Chainmen, Flagman, Axemen, composing the party. Rodmen must make the same notes, also enter the date and place where the work is.

Second—State in the column of remarks on the first or second page of the book at the beginning of the notes of any survey or levels, the letter of the line and where it was begun and where it is to be run to.

Third—The Stakes of all lines must be numbered on the rear face, next to the transit, and must be lettered on the forward face, with the letter of the line. All lines must be lettered.

Fourth—State what Datum the Levels start from or refer to, and if started from a Bench state what Bench and from what authority or book the Elevation was obtained.

Fifth—Enter all notes of Transit or Level fully and distinctly in pencil in the field—if any details or calculations are omitted from haste or sudden storms coming up—make them complete before the day is over, and when required by the Senior Assistant or Division Engineer, they must be recorded in a Record Book the same evening.

Sixth—All field notes must be compared during the day taken, and all Levelers' calculations on turning points must be made by Assistant and Rodman, and compared on the spot and found correct before going forward with the work.

Seventh—Benches must be made at least once in every mile, and oftener if opportunity offers. Levels must be tested on any existing Benches found along the line, and tests made of the accuracy of the old and new works. Benches must not be cut on shade or fruit trees and no unnecessary damage done in clearing the line of sight; offsets must be made to save valuable trees

Eighth—In passing through inclosed land the Senior Assistant will see that the fences taken down by the party are put up after they pass forward.

Ninth—The Assistant at the Transit must record the names of land owners, the points where boundaries are crossed, and their courses when obtainable.

Tenth—Chiefs of Party must arrange to get the party out and at their work as early as possible in the morning, and keep them employed until the proper hour in the evening. All preparations for the field work must be made by the Senior Assistant and Assistants the previous evening, so that no delays may occur in the morning. Dinner will be procured by the Senior Assistant to be eaten in the field when the party is more than one mile from boarding places.

Boarding expenses paid by any members of the party will be reported to the Senior Assistant and will be repaid by the company at the end of the month.

Eleventh—Senior Assistants will see that the instruments, rods and chains are kept in good order and adjustment by the Assistants; any damage to instruments or rods from want of proper care must be defrayed by the Assistant having the same in charge.

Twelfth—Daily notes of the work done and the date must be entered in this field book every evening.

Thirteenth—Assistant Engineers in charge of the Transit must plot their lines, and Assistants in charge of the Level must, with the aid of their Rodman, make a profile every evening, of the line leveled over each day.

Fourteenth—Division and Senior Assistant Engineers will make reports of instruments and stationary on hand at the close of each month, and send them in promptly to the General Office.

Fifteenth—Division Engineers must report any neglect of these instructions to the Chief Assistant Engineer.

OLIVER W. BARNES, Chief Engineer.

Engineering Field Work.*

CHAPTER VI.

THE SURVEYS.

The three classes of surveys, viz: Preliminary, Location, and Construction, form as good divisions as can be suggested for this subject, and we will consider them in order.

PRELIMINARY.

The object of a Preliminary survey is to ascertain whether it be feasible to build a line of railway between two points upon the surface of the earth, and this information is obtained for certain parties who wish to make money in some way or other by constructing or having such line of railroad constructed. For this purpose the parties employ a more or less competent engineer to make these surveys, giving him authority to employ one or more field parties according to the magnitude of the work, and the money they may think they can spend upon it. If only one party is employed it is sometimes under the direction of the chief engineer himself, but more commonly under an assistant employed by him.

ORGANIZATION OF FIELD PARTY.

The organization of this field party is usually, as follows:

1. The Assistant in charge of the party.
2. The Transitman, whose work is running the line and keeping all notes thereof.
3. The Leveler, whose work is taking levels, drawing the profiles and making the estimates therefrom.
4. The Level rodman, assistant to the Leveler.
5. The head chainman, who should also carry the transit rod and get therewith the lines given by the transitman.
6. The hind chainman, who should also number the stakes and keep a record of all distances measured.
7. From one to five axemen according to the amount of chopping required by the work.

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* Written by the late CHAS. A. SMITH, C. E., Professor of Civil and Mechanical Engineering at Washington University, St. Louis, and published in ENGINEERING NEWS, Vol. III. 1876.

These may be considered about all the men needed for the professional part of the work, and if the country is inhabited will be all that will be employed; if there are only a few inhabitants a team and driver may be advantageous, but if uninhabited and it becomes necessary to take a camp outfit, at least two more men are indispensable—a teamster and a cook, the latter being a very important member of the party.

THE ENGINEER-IN-CHARGE.

The duties of the engineer-in-charge of the party are too many for enumeration here, but he has to see that the greatest amount of work possible is done for the money expended; his business is to get information for the chief engineer and to keep his party running without delay. A word of brotherly advice to him may not come amiss and is meant kindly if it is not necessary.

CARE OF MEN.

In selecting your party for a start use judgement and your knowledge of human nature; don't get two men who have a feud with each other in the same party if it can be helped. Study your men all the time and be frank and free with them; do not talk much with them in working hours, but watch all hands very closely, for the first few days especially. Remember that your men are men, and treat them well; show them that you know how the work should be done, but don't "nag" them all the time; if you have a horse, don't keep them at work till dark and then ride off and leave them to walk three or four miles to supper, but either quit work in decent season or lend your horse to some fellow who is fagged, and walk in with your men; don't hang round in the morning and let your men wait for you, but pick up an axe or rod and start first for the work; get into good training for walking, and if you start for supper last passall the men on the road; don't shirk work yourself, and don't let any body else shirk; never ask a man to do any work you would not be willing to do yourself,—we remember "stripping to the buff" and wading a stream four feet deep when the cakes of ice were coming down, because we thought the men hung back and did not want to go into the water; don't worry the transitman's wits out of his head by asking him questions; find out what he is doing and recording, but don't crowd him too hard or bluster about him; don't swear habitually before the men if you

can help it; you may want to swear at them some times, and if not used to it they will be more apt to obey; don't scold a man when you are angry yourself, if you can help it, but wait and talk to him after supper, when you have cooled down.

THE COOK.

In selecting a camp outfit be especially careful to get a good cook, and we advise a good cooking stove of cast iron with enough pipe to draw well,—we remember a sheet iron stove which had to be taken down every morning and the soot kicked out of it before a fire could be made to "draw," and we also remember the satisfaction with which the boys kicked the miserable thing to pieces after it had been "returned" at headquarters. We are more particular in this matter, not only because we like to be well fed, but because men must be well fed in order to work well—and you must remember that poor food will make bad temper and bad work, and that the interests of your employers demand that you keep your men contented with their job. So much for the *care* of the men.

ON THE LINE.

Don't let your leveler get too far behind the transit work, and see that he checks his levels and establishes benches at proper intervals. After the work is well started you will be obliged to go ahead and make yourself familiar with the features of the country and select the points where your line must be run. A preliminary line is usually run without curves, and the work of the transitman is much easier than in location surveys, and the line work is much more easily carried on than when locating; and this brings us to the work of the transitman. But before leaving this part of the subject let me remind you, that as your work progresses, you will have to come in contact with the property holders and residents of the country, and you should always bear in mind that you represent large interests and can give them by your manner a favorable or unfavorable impression as you choose.

THE TRANSITMAN.

The transitman has the hardest work of the party to perform; he has to stand with one eye at his instrument as long as the men can set stakes, and then when he is called up, the whole chain and axe force have to be idle till he arrives at the place where they are

and has set up and lined his instrument; he is supposed to direct the work in the absence of his superiors, to know the topography of the country ahead and run his line to suit the ground—to keep all the men at work and not let them loaf around—to keep all notes, and if possible sketch all the topography; to act as chie assistant in every way, to be book-keeper and cashier of the party; if in camp, to purchase supplies and see that things go right generally. The skill of the transitman in the field consists in his realization of the peculiar features of the ground and his judgment in running to them, and to his being able to work under mental pressure. The mere instrumental work in a preliminary survey is easy to do, as it consists only in running bearings, noting angles and giving the line to the men at the chain. A few words to the transitman: Carry your instrument yourself; don't let any of the men take it at night unless you are just ready to drop with fatigue. Your men may very probably offer to carry your instrument, as a common courtesy, or even to make friends with you, but don't accept such favors; among working men, from which class your chainmen and axemen will most probably come, there is but one standard of comparison, and that is strength, and although one of them may be perfectly willing to shoulder your fifteen pound transit for three or four miles, you will not gain his respect by letting him do it for you. If you have not strength, make up for it in endurance and quiet pluck, and if you want to grumble, don't do it before the men. You and the engineer-in-charge must be in perfect accord, at least in appearance, if you want to further the interests of your employers and your own also. In setting up a transit on sideling ground it is generally better to put one leg of the tripod up hill and two down, but you must exercise a little common sense in the matter; try to keep the lower "parallel plate" as level as possible, as by so doing time in "leveling up" will be saved; try to make yourself master of your instrument as there is a great range in the value of transitmen, and try to "set up" each time a little quicker than before, and also a little better. The acme of setting a transit may be considered reached when one shove on each leg of the tripod brings the "plumb-bob" exactly over the point in the stake, while the instrument is found level "both ways." Try and see how many times you can do this every day, but don't waste time studying how to do it at each "set." It is rather better to keep the plates clamped together at zero, and do all lining of the instrument with the lower clamp and tangent;

take bearings on both fore and back sights as you may detect errors in reading angles by so doing, and be careful to record which way angles are turned. It is most convenient to run your transit ahead always and read the same end of the needle if the instrument is in as good adjustment as it should be. The stability of the adjustment differs very widely in different instruments. We have worked with an instrument for three months which never had to be touched, and also with another from the same maker which would not reverse truly for the day, although adjusted every morning; it becomes necessary, therefore, to learn the peculiarities of your instrument, and know, not guess at, its condition at all times. The reversal should be tested each morning before going to work until you are sure of the instrument. Learn which way to get the slack of the tangent screws, and to do good work with a poor transit.

THE LEVELER.

The leveler on a preliminary survey may have to work at his best to keep up with the transit party, and as the leveler and rodman have to work completely in unison, we will give them our advice together after their field work. Of course, in the office, or in camp they are two very different people, the leveler being one of the commissioned officers of the party, if we may use a military term, while the rodman is about the grade of a sergeant only. Still there should be very little difference of feeling between them. The leveler keeps all field notes and the rodman should also carry a book and keep the turning point sights and work out all heights of the instrument and elevations of turning points and benches in the field. Readings for turning points and benches may be taken to the thousandths, but for station heights the nearest tenth only should be read.

LEVELING.

Make all the vertical height you can in going up or down hill as you may save a setting thereby. Study the ground as to what is coming ahead and never select turning points or set up the instrument without having fully considered what is to be done next.

Be sure of the adjustments of the instrument and that the rod is held "plumb" (if the cross hairs are right, the man at the instru-

ment can see by the vertical hair if the rod is "plumb" one way, and by gently swinging the rod in the plane of the instrument after setting the target if the target rises above the hair, the rod was not held "plumb;" if the target on swinging the rod, falls below and just comes up to the hair, the rod has been held vertically). Make your signals with some system, and move the rod according to the signal in amount of motion as well as direction, speak your numbers distinctly and don't mistake the word seven for eleven, or the reverse.

Leveling can be hurried in open country by employing two rodmen and rods, and running them alternately, the employment of a fourth man to keep notes in such case being a great help, although such great haste is not often required or desirable.

Put in benches at least once in 1,500 feet in open country, and every 1,000 feet in rough country, as it may save you a good deal of work; select good points for benches and turning points, and always be sure that the instrument may be moved before you move it, and that you can find at least half of the turning points in the day's work.

In running "check levels" check up the benches every mile, and if the agreement is within one-tenth, call bench right and go on. Try to keep the check levels within two miles of each other, as it may save a good deal of annoyance.

The work of the rest of the party is much the same for location and preliminary surveys, and will be described further on. The engineer in charge of the party and the transitman are the ones whose work is increased the most, and their duties will be described again for location survey.

THE HEAD CHAINMAN.

The head chainman holds an important position and must be a man with sound judgment, and must understand his work. He should hold the transit rod with one hand, and the chain with the other, showing discretion as to holding the chain level and taking short lengths on hilly ground; he should understand the signals of the transitman and obey them intelligently; should have a good eye for line and use it every time he holds his rod up, so as to be as nearly right as may be before the transitman begins to signal to him; and he should always look at the transitman when lining, instead of gazing around at other things. His work is perhaps best conducted in the following order: When the chain is pulled out

he turns around, and holding the rod with one hand, tries to place it as nearly correct as he can by lining over the last stake to the instrument, while with the other hand he is trying to "straighten out the chain;" he then moves the rod in obedience to the motions of the man at the instrument, and after getting the line, holds the chain up to the rod with both hands and gets the distance; then dropping the chain he stands up straight, plumbs the rod carefully and receives the line again; then pressing the rod into the ground he makes the hole with the point, and takes it off the ground: a stake is then driven and the measurement should be repeated to see if the distance is correct, after which the rod is held on the stake "for line," the chain is then dragged on and the operation repeated. Time may be lost by neglecting the order of operations given above, or by not looking to see where the line is, and leaving all the movements to be signalled from the instrument, or by jerking the chain while trying to straighten it, or by not watching the transitman closely, and thus missing his signals. If you are so far away that the motion cannot be seen, take your handkerchief or hat and make a signal (imitating the lining signals) and the transitman will understand that you wish him to take his handkerchief, (when snow is on the ground, his hat) to increase the visibility of his signal. Remember that the transitman can see you plainly, and can guess what you may wish him to do. When you wish him to line you hold up your rod and wave it to catch his eye, and when you are sure that the line can go no further without a change in the position of the instrument, you must call his attention by holding your rod in both hands horizontally above your head; then after carefully lining and centering, you can call him up by beckoning with both hands, holding the rod above your head or by any other previously arranged signal.

SELECTION OF TRANSIT POINTS.

By far the most important duty in point of difficulty, is the selection of the transit points, which must be so chosen that the greatest distance ahead may be seen from them; in general they should be on the upper edges of hills, where a view of the valley on both slopes can be obtained, and if possible, where a full view of the transit rod can be had, as it is only allowable in case of necessity to sight at but a small part of the rod, and therefore great care must be taken to hold "plumb" at all times, as you do not know just how much of the rod may be observed. You must exercise consid-

erable judgment in the matter, and never be astonished if your views and the transitman's differ on this point. And here let us say a word to all the men; remember that the transitman has to work all the time, and that he has to take all the blame from the engineer-in-charge for all mistakes, and that if he does scold you for things that are not your fault, just wait till the matter developes, but do not try to argue during working hours about the work; if you have been to blame, you deserve "jawing," and if you have not, it will not hurt you a bit in the eyes of anybody whose opinion is worth having. The same remarks will apply to the transitmen and levelers in their relations to their superior; let them remember that the engineer-in-charge has more things to think about in a day than they have in a week, and if they don't believe it, wait until they have the same position and can see for themselves.

THE REAR CHAINMAN.

The work of the rear chainman is to hold the chain while it is being pulled along; we say hold it, for if you let the end go you may have to call the front chainman back for 10 or 20 feet after he has passed his proper distance, and he won't like that. Don't hang on the chain and be dragged by it, but be ready to give it a shake and clear it if it catches on brush or rocks. The rear chainman is responsible for the numbering of the stakes, and for all distances with "plus" numbers; he must be careful to assist in straightening the chain, to be on hand promptly in measuring, and not get in the line nor walk on the line, and not to jerk the front chainman's arms off by suddenly stopping. The keeping of the numbers right is a more difficult task than it seems to be, and requires a good memory; in all cases of doubt, go back and find out at the last stake what is right and don't guess at it. Be careful that the chain is in good order—that the links are straight and that the rings are not pulled open. Do it up from the handle and keep the strap around it; learn to throw a chain over a stream; one end of an ordinary heavy chain can be thrown over a 50 feet stream. And by making two bundles with say 15 feet between them, and using two men to throw, one after the other (at say half a second interval), we have thrown the end of a heavy chain 75 feet. Be careful that the chain is not dragged against the transit legs, and do not hit them while trying to stand the straightening as inflicted by the head chainman; be prompt to assist in making short chains on hilly ground, and on curves, if there are any, and walk the outer side

of the line lest you get in the "line" of the instrument without knowing it.

THE AXEMEN.

The axemen are under the general direction of the head chainman who gives the line for cutting brush and timber with his rod. One axeman must be in charge of the stakes and must never let the chain work wait for him a second, but must keep up at all risk. Sometimes a large basket is useful in carrying stakes. The stakes should be numbered by the chainman, and if he marks a number of them in the basket, care must be taken to see that in "plus" stations the numbered stakes are not used, or the numbers may get "mixed."

LOCATION.

In location surveys the only difference in the work of the men is in the curve work, where the head chainman has to offset from the line of the last stake to find the transit "line" by an amount known as the chord "deflection," for which see "Henck's Field Book." We always gave the chainman a list of "chord deflections" for the even degrees, and let him guess at the amount of the ground, and found that it saved time. The centering of the stakes should be attended to a little more carefully than on preliminary work, and the measurements made with more care.

A back rodman will be necessary, and we can only caution him to stand up, with his rod in position all the time, or if near enough to see, whenever the transitman turns over his telescope, he must be on hand. Although the job is not very interesting it is important. We used to let the back rodman carry the coats, and if we took our dinner along, a basket with the "grub."

Each man in the party must be held strictly responsible for what tools or instruments are put into his hands, and a careful property account must be kept and reported from time to time.

WASTEFULNESS OF CARELESS LOCATION.

Location surveys differ from preliminary surveys in being more carefully carried out, as to the exact position of the line, and in the curve running, which is usually omitted on the preliminary work. The exact position of the line is a matter of great importance, for many dollars are thrown away by careless locations and in many cases the theory of wilful ignorance is the only excuse that can be

made for them. There are needed careful judgment, long experience, and a great deal of real hard work on the part of the engineer in charge of the locating party, to make successful locations.

THE TOPOGRAPHER.

The party is usually organized with the same force as in the preliminary survey, viz: An engineer-in-charge, transitman, leveler, level rodman, two chainmen and from one to five axemen. To these are often added a topographer, and sometimes a cross-section leveler and helper or rodman. The topographer takes sketch-notes of the contours and surrounding country, roads, buildings etc., which have to be shown in the plans, and if he carries a pocket "azimuth compass," or a pocket sextant, he will find it a great help to him, but for his work we especially recommend a small plane table, 18 inches square, with the paper on it in "block" fashion, the board fitted with a shoulder strap, and Jacob staff mountings, and a folding "alidade" or ruler, with sights. With this outfit a topographer can produce a line map which will make his chief engineer's heart glad, and which will go a long way towards convincing the directors that the party have done a lot of work. The use of the plane table for this purpose is not common, but such an arrangement costs very little, and nothing else will show as much of the country in a very short time. The field use of the instrument is very simple; the line already run being platted before taking the field, the "orientation" can be performed from stakes and it can be used anywhere.

The cross-section leveling is only performed in very rough country; a 10-foot pole with a short spirit level placed on it, and then held with one end on the ground and the other against a graduated rod on which the rise or fall in 10 feet is noted, is used; the information obtained in this way is very considerable; there is a good deal of work to get it but the men are not required to have a very high grade of mental organization and do not draw a very high pay.

ENGINEER IN CHARGE.

All of the increased care and skill required and already mentioned has to come from two men—the engineer-in-charge and the transitman—the former has all the responsibility of the added importance of the survey, and the constant study of the ever changing ground, and the greater or less difficulty of the work itself; and

the latter has all the curve work, with increased watchfulness and greater accuracy, to attend to; those two men have their work nearly doubled, while the work of the rest of the party is only increased by the additional care and attention which has to be enforced on all the party.

To the engineer-in-charge we shall say very little, and to a man in that position little can be said—if he does not know his business he certainly ought not to be in the place, and if he does know it, our advice is unnecessary, yet if he does not think it beneath him to read what we have to say to transitmen, he may here and there find a hint to help him in watching the work of that indispensable assistant. And here let us say that no money is ever saved by making the engineer-in-charge of the location run either transit or level, as he needs all of his faculties to be at all times sharpened to their utmost degree to attend to his own duties, and if the tedious instrumental work is put upon him he cannot keep everything going at once properly. And let us say also, that if the engineer-in-charge wishes to make every man do his very utmost, that he had better take the head of the chain himself when he can spare the time, especially on long tangents, which he has already determined. By so doing he will be near all the men of the transit party, and they will work when they are right under the eye of the "boss," and he will be sure that no time will be lost in picking out the transit stations, and that the stakes are kept well up; the transitman will always hurry up to him, and if he cannot keep them all "on the jump," he is not fit for his place. Of course, he has frequently to go ahead and pick out the ground, and go back to see how the profile will plat, and tell the transitman what must be done in his absence, and in this he must be his own judge of his time and of its disposition, but still, when he wishes to drive matters, he can do so best from the head of the chain, in the meantime letting the head chainman take the transit rod and keep up the centers; the mental work which he has to perform all the time will not suffer from the mere manual labor of being head chainman.

KEEPING TRANSIT NOTES.

The transitman has after all a hard place to fill, for there is no variety in his mental work; he has to keep a sharp watch on the men when his superior is absent, and has the constant computation of deflection angles to attend to on curves, at the same time

using all possible diligence as to figures. And here a hint as to the easiest way of keeping the curve notes and doing the transit work. The method originated we know not how, and may have have been used by large numbers of transitmen, although we have never happened to meet them.

The basis of all circular curve work with the transit is the well known theroem: the angle between a tangent chord, or between any two chords which meet at a point on the curve, is measured by half the intercepted arc. And as the point where the chords meet on the curve may be anywhere on that curve, it follows that the sum of any consecutive angles or series of angles is the same no matter where the instrument be placed on the curve for given arcs, and that if the deflection angles be all computed from the B. C., as far as may be desired, at any station on the curve the number can be used, as the differences will be the same for the same stations. To illustrate this, we must assume an example.

Let it be required to run a five degree curve from sta. 131 + 40, and let us first look at a page in a field book:

STATIONS.	DEFLECTIONS.	CURVE.	TRUE COURSE.	NEEDLE COURSE.
129			N $16\frac{1}{4}^\circ$ W	N 16° W
130				
B. C. +40	0°0′	5°R.	N 16°15′ W	
2	1°30′			
3	4°0′			
4	6°30′			
5	9°0′			
+50	10°15′			
6	11°30′			
7	14°0′			
8	16°30′			
E. C. +25	17°$7\frac{1}{2}$	34°15′	N 18° 0′ E	N $17\frac{3}{4}^\circ$ E

We see the book is ruled with five columns and usually on the left hand page, the right hand page being reserved for "remarks." The column for Stations explains itself, the signs "plus" being used, decimal points for a hundred foot unit, and the ordinary "decimal" being reserved for feet and fractions of feet. The letters B. C. and E. C. are used for beginning and end of the curve, instead of the P. C. and P. T. used often for "point of curve" and "point of tangent," being more in accordance with the usage of ordinary geometry and has been our custom for several years.

The column of deflections contains the deflection angles computed from B. C. as far as convenient, say to station 135, and the stakes set and centered, for same reason 135 + 50 becomes necessary and has to be put in; then the transit is turned back to 0° and turned over on the back sight to be sure that nothing has slipped and carried up to 135+50, and set up. The instrument is then set at 0° and sighted at B. C. and then if turned to 10° 15′ it would be on the tangent at 135 + 50, and if turned to 11° 30′, it will be on the chord from 135 + 50 to 136, and by adding these 2° 30′ for each hundred feet the curve is run to 138 and the transit is moved to that place after taking a back sight as before, with the plates at 0°. After setting up at 138 if we could see B. C. we should set at 0° again, and turning to 16° 30′ we would be on the tangent; but B. C. is supposed invisible, and we shall therefore set the instrument at 10° 15′ and sight it back at 135 + 50 and the result is that the lower plate is in the same position as if B. C. had been visible, and we had as above suggested set 0° and sighted thereat; by turning to 16° 30′ we shall be on the tangent at 130 and if we find that 1° 20′ more will be needed to strike the desired direction from there, we will put 1° 15′ more in the curve or 37½′ deflection which corresponds to 25 feet; we run out the 25 feet and turn to 10½′ and sight the stake in, and then turning to 10°15′, we turn over to the back sight; after satisfying ourselves that it is all right, we go to 138 + 25 and being sure the instrument reads 10°15, we sight again at 135 + 50 and turn to 17°7½′ and are at the tangent. By taking the differences and comparing distances it will easily be seen that the angles are all right.

Now in what does this method consist that is better than the practice of counting stations and multiplying by the deflection angle? Only this, that the counting and multiplication are both performed already. Each station is attached to the angle opposite to it in the note book, and once there it is good for all the work that you can do with it. The mental labor thus saved is a great help. It was once our fortune to have to "break in" two "green" transitmen in five weeks, and in all that time we computed every angle that was used at the instrument, mentally, and kept at the head of the chain most of the time; by asking the man at the instrument what reading he had and what station he was at and what his back rodman was at, we never let a mistake pass our notice. (*Note.*—We are not anxious to repeat this experience of our transit running from the head of the chain.)

For the transitman himself this system of notes is a great relief as he is free from the constantly recurring question "what is your next deflection?" with its importunate worrying when he has just set up on an odd "plus" and knows that his back rodman is also on an odd "plus," he simply asks himself, what are the readings for these two stations knowing that the difference between them has been computed carefully once as they come along, and it will be all right now.

COMPOUND CURVES.

On compound curves the same method can be followed all around, but the back rodman and the instrument must be on the same branch (the P. C. C., point of compounding of curve, is of course on both branches). The next column of the note book is headed "curves" and in it are recorded the degree and direction of the curves and the central angle,or angle of intersection; it is twice the last deflection angle always. In the next column is put up the computed curves from the first one, and the next one contains the needle readings; the use of these is a check to the transitman's work and sudden variations are not common. If "local attraction" exist, it can be found by reading the compass at each end of the tangent. We remember a local attraction which bothered us all one morning and which never seemed to be the same for two minutes running, and which quite frightened our "boss" but as we were within fifty feet of a north and south track, we talked "earth currents" at him (they were east and west) and as we were sure of our work we let it go unexplained; in the afternoon we discovered the innocent cause to be a small "Smith & Wesson" in our overcoat breast pocket, and we have never seen any such local attraction since.

LONG TANGENTS.

Long straight lines require a good deal of care, and the instrument should be reversed "both ways" on them, and if a long sight can be obtained backward so as to overlook two or three transit points, they should be tested by the direct instrument. If great care is needed, the instrument should be used "both ways" without reversing, and the slack of the clamp screws watched. Tangent screws are now so generally made double that the play of the motion screws can be prevented from interfering with the ac-

curacy of the work, but the clamps will wear loose a little and must be watched.

LAND LINES.

In Railway field work, after the location survey, follows legitimately the land survey or "land lines" as they are called in the east, and although most of this work is included in common surveying, yet there are some points of difference which it will be well to touch upon. In cities and towns where land is valuable, it is of course quite important to have the work done accurately; and although in the western country, where the land is very commonly given to the railroad company it is not so essential, still it is always desirable to know how to do good work, and a few words as to general surveying will scarcely be out of place.

In the first place be sure that your work is definitely connected with points which can be found again, and that the connection with the main line is right, and that it is simple; any complex measurement is to be avoided. In the next place, measure every distance pertinent to the work which can be directly measured. Calculate as little as possible. If the land to be taken is very irregular in form, a "traverse" is the best method of attack if all the sides can be measured; don't have any "omissions" to supply if you can help it; be careful to take all offsets at right angles; take the angles with a transit if one can be had, and do not use the compass in any way but as a check on the transit; for sighting right angles quickly, some of the forms of the "optical square" may be found very convenient; for ordinary work in cities most of the measurements for land will be at right angles or nearly so, and the work can be laid out on four lines forming a trapezium; do not trust to any building for a right angle or to any two walls of the same building to have parallel faces; brick laying is not by any means the most exact of trades, and although for a map the errors will not show, yet for other work to be connected to that in progress, it may lead to serious errors.

For railroad purposes the land is usually found in long narrow strips of varying width; and it is sufficient to find the length on the centre line, and directions of bounding lines which cross; it is however, desirable to have all "land lines" within four or five hundred feet of the track, and this requires measurements on the crossing lines. In getting the direction of a fence, when the instru-

ment is placed at one side, measure the distance from the instrument to the fence at right angles to it and have a similar "offset" made as far as possible from the instrument; of course the main line should have been run and the transit placed in the line before the direction can be obtained.

For street surveying the best method is that of a line in the middle, with offsets and measurements connecting, the offsets at the end as well as the line run. In very crowded streets we have sometimes run a line down each footwalk, connected them carefully at their ends, and then proceeded as described for a single line.

CAREFUL NOTES

In all work of this kind the most important thing is to take good notes; always put these down as if you expected to die before morning, and wanted to leave them in such good condition that in ten years time a stranger with no previous acquaintance, and with no one of the old party to help him, could take your book and proceed on the job without delay; if this can be done, your notes must be about right, but you never will have them too complete. We have never used any but the "sketch system" for taking notes, and we always made them in the field, and copied them over on the next page in ink, thus keeping the rough set with the original figures, and the finished set to explain them; the original figures have more weight as evidence, but the explanation given by a neat ink copy is a very great help in interpreting them. For city work take all angles with the transit more than once, that is to say, "repeat them," three or four times which is enough; the object of the "repeating" being to check the angle and not to subdivide the vernier reading.

PRESERVING THE LINES

After the completion of the land survey comes the actual field work preparatory to the construction, and here it is customary to reduce the number of men in the party and to begin to "cut down expenses" in the engineering department.

The first thing to be done is to "preserve" the line, that is, to connect all tangent points with stakes that are away from the line and far enough from it not to be disturbed by the operations of grading and earthwork; at the same time the slope stakes should be set and marked with the cut and fill—also the cut or fill should be marked on the centre stakes—this work can all be done on the same job, and

thus the contractors can make a start at once if they so wish; of course a record of all field work is required, and the results should all be put in the grade book. For setting slope stakes the only satisfactory method is with the Leveling instrument, though for comparatively smooth ground and light work, there are various devices for setting slopes which involve much less work, and are sufficiently accurate for use.

CENTRES AND GRADES.

Most of the work for railroads in construction consists in setting "centres" and "grades;" for the former, in nine cases out of ten, the line can be run in without an instrument, if the known points are convenient; the Tangent Deflections are useful for running curves with only the chain and rods for lining; for approximation there is a very convenient method of computing angles and distances (measured as arcs) which it is well to be familiar with in the absence of all "pocket-books." At one hundred feet distance three-hundredths of one foot subtends one minute of arc. Strictly speaking it is twenty-nine one thousandths instead of three one hundredths. At the same distance one foot and three-quarters subtends one degree of arc, but one and eight-tenths can generally be used. With this once fixed firmly in the mind, mental computations can be made with the greatest ease. As an example of this let it be required to find Tangent and Chord Deflection for 100 feet chord, and for 60 feet chord, and ordinate at centre of 100 feet chord for a 5° curve: $5\times1.8=9.00°$ for the Chord Deflection, and 4.5′ for the Tangent Deflection 100 feet chord: $4.5\times0.6=2.7'-2.7\times0.6.=1.62$ Tangent Deflection for the 60 feet chord, and $\frac{1}{4}$ of the Tangent Deflection for 100 feet chord $=1\frac{1}{8}'$ for the middle ordinate. These values are all in excess, and if the deflections are to be used for running the curve more than one station, the value $1\frac{3}{4}'\times5=8\frac{3}{4}'$ should be used, and this is in error only about $\frac{3}{8}$ of an inch. A great many other computations may be thus performed mentally, and the work already done checked by these approximations, and the real blunders found.

QUALIFICATIONS FOR LEADER.

There are many ways of doing most kinds of field work, and many methods are described in the books under various heads—but a good knowledge of geometry and trigonometry, and possibly a little familiarity with analytic geometry, combined with a cool head, and an appreciation of the external circumstances, will en-

able a man, after a limited experience, to become competent to take charge of a party in the field, as far as the mere theory of the operations is concerned—but a knowledge of human nature and sound judgment are required to give satisfactory results.

CULVERTS AND MASONRY.

We would say a word about the staking out of culverts and masonry, and will begin with a hint about box culverts. On masonry of this class it is well to put in four stakes on the lines of the face of each wall, one at each end of each line, and two stakes, one on each end of a line terminating the culvert at the proper distance out, found as in slope stakes. These stakes must all be placed outside of the trenches, and should be at such a distance from the work that they will be safe during the construction.

BRIDGE ABUTMENTS.

Bridge abutments on shore can be given in the same way, and if in the water by parallel lines, or sighting frames made out of strips of wood. Piers can be located by sights on shore, or as they are commonly termed "ranges."

EARTHWORK MEASUREMENT.

If earthwork is to be measured in a "borrow pit," the best way is to run out two sets of lines at right angles over the ground, denoting distances in one direction by letters, and in the other direction by numbers, and taking the levels all over the ground denoting the stake by both letter and number, and then every month as the work is done, these stakes can be replaced and the levels taken again. The bounding lines of this system should be carefully put in, and the stakes may have permanent "sights" put up over them; in this case the stakes of the system can be replaced without a transit. Of course the bounding lines should be wholly outside the work and there can be little trouble in taking care of the work in this way.

RETAINING WALLS.

Retaining walls are very usually set out by stakes, but "sighting frames" outside the wall and in line with it are to be prepared, if the height is not too great.

TUNNELS.

Underground work in tunnels is usually kept in line and grade by points on the roof; their stability and permanence are much greater than if given on the bottom of the tunnel. In rock work where stakes can not be used, chisel marks are made to serve as points. Such work requires less frequent attention, but is more important.

RESPONSIBILITY OF ENGINEER.

And now in closing, let us add a word as to the responsibility resting upon the engineer when setting out work.

Few beginners appreciate the necessity for correct work, and do not realize that a blunder undetected may cause a loss to the contractor of a great deal of money, and that if he, as the company's authorized agent, makes a mistake in his work, the company may become liable for many times his salary, and that his discharge is a very small amelioration of matters which he has mixed. Pecuniary responsibility must be fully appreciated in order to have accurate work done.

Mistakes in work are not only discreditable but they are dishonorable, and to the feelings of the suffering party they seem criminal. Now as man is liable to error, work must always be in some way checked, and a mistake which is discovered by the maker in time to be rectified by him before any damage is done is in no way discreditable, provided however that it does not happen too often, and that the same class of mistake is not made the second time. Nothing gives a contractor less respect for the engineer than finding his mistakes, even if they have caused no damage.

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